Support for
Wind Power Development in Mozambique

A study of the feasibility of wind power in the southern Mozambique

Final Report (Draft)

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DNER **Risø** **Danida**

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The present report documents the work in and the results of a study entitled ‘Support for Wind Power Development in Mozambique’, carried out in the period from Nov 2006 to Mar 2008. The report is edited by RISØ National Laboratory, Denmark, as Technical Consultant, and the Ministry of Energy, Mozambique, as the project manager and owner of the study.

The report is public.

Front page photo: DNER staff at the Tofinho met-mast east of Inhambane (photo: Risø, 2007)

Executive summary

The project *'Support for Wind Power Development in Mozambique'* has been carried out in the period December 2006 to March 2008. The Project was supported by Danida, was executed by Renewable Energy under the Ministry of Energy (DNER), Mozambique, in close collaboration with Electricidade de Moçambique (EdM) and with Risø National Laboratory (RISO), Denmark, as Technical Consultant.

The Project included

- an assessment of the wind resources along the coastline in the southern part of Mozambique – from the border to South Africa to Inhambane;
- a technical feasibility study of wind power connected to the EdM South power system; and
- an economic and financial feasibility study of wind power in the southern part of Mozambique.

Only grid connected wind power has been investigated within the present Project, and only in the southern part of Mozambique. The EdM South power system (the Maputo power system) is connected to the rest of the EdM power system in Mozambique only by power transmission lines via South Africa. The dominating load in the Maputo power system is the Mozal aluminium melting factory, with a constant load of around 900 MW (2007). The total remaining annual consumption in the Maputo power system is 1.3 TWh (2006), with a peak load of 200 MW (2006). The main contribution to the power supply in the Maputo power system comes from import from South Africa. The 16 MW Corumana hydro power plant is connected to the Maputo power system. However, its generation is restricted due to lack of water inflow to the corresponding Corumana Dam. Another hydro power plant (Massingir 25 MW) is considered.

With the presently relative little power generation capacity in the Maputo grid, with a minimum load of 100 MW (exclusive Mozal), and with a transmission grid designed for 200 MW peak load in Maputo, supplied from South Africa, 100 MW wind power capacity can easily be integrated into the Maputo power system. The wind power generation will simply substitute the import and thereby also reduce the power transmission losses.

As part of the present Project, dedicated wind measurement equipment was installed at two selected locations along the southern coastline – one close to the border of South Africa – the Ponta do Ouro site – and one east of Inhambane – the Tofinho site. The sites were selected based on wind data available and on inspection of potential sites. The wind speed, the wind direction and the air temperature have been measured up to 30 m height levels at both sites for a period of one year – from March 2007 to March 2008. The stations have been operated by the DNER. Based on the one year measured wind data series, correlated to a long term wind data series from Maputo Airport, the long term wind resources have been estimated, using the WAsP modelling tool.

The wind resources correspond to an annual power generation of 2-2.5 GWh per MW installed wind power capacity (corresponding to loads factors of 25-30 %) – depending on the specific site and the type of wind turbines.

The feasibility of establishing wind farms have been investigated south of Maputo, next to Inhambane or in the Limpopo River valley. A 10 MW wind farm has been used as case for the feasibility analyses. South of Maputo, a 10 MW wind farm can be connected to the Salamanga power substation, next to Inhambane, a 10 MW wind farm can be connected to the Lindela power substation, and at the Limpopo River the wind farm can be connected to the Xai-Xai substation. In all cases, the wind farms will be connected at the end of a power transmission line. In all cases, the short circuit levels are sufficient, and the wind power generation will reduce the need for power transmission, and thereby reduce the resulting power transmission losses.

The total investment cost of the wind power – inclusive the grid connection – is estimated at € 2 mio per MW wind power capacity, and the long term cost of wind power is estimated at 100-200 €/MWh.

The value of the wind power over the 20 year expected life time is very uncertain.

Findings and recommendations

	Findings	**Recommendations**
1)	Based on 30 years of wind data for Mozambique from the global meteorological database provided by NCEP/NCAR, the best wind resources in Mozambique is expected to be found along the coastline in the south of Mozambique.	It is recommended to check if the wind data collected at the airports in Mozambique match the results from the NCEP/NCAR database, indicating a quality to form the basis for a verification of the general distribution of wind resources in Mozambique.
2)	The wind resources along the coastline in the south of Mozambique correspond to annual wind power generation of 2-2.5 GWh per MW installed wind power capacity. The wind resources expect to decrease with the distance from the sea, but this has neither been verified nor quantified.	It is recommended to quantify the general change in the wind climate with the distance from the sea, by simultaneous wind measurements close to the sea and some kilometres inland during a one year period.
3)	A good site for a pilot wind farm project has been identified at Chicumbane. However, the actual wind resources at this site are rather uncertain.	It is recommended to verify the expected wind resources at the Chicumbane site by doing wind measurement at the site.
4)	The total investment costs for large-scale wind power in Mozambique are estimated at € 2 million per MW of installed wind power and the generation costs are estimated at 100-200 €/MWh (2008).	

	Findings	Recommendations
5)	The wind speed at the Maputo Airport seems negative correlated to the water inflow to the Corumana Dam, indicating a potential added value of wind power in combination with hydro power. The variation over the day of the wind seems positive correlated to the variation of the Maputo load, indicating an added value of the wind power. The value of the wind power generation is very uncertain and highly dependant of the situation and the development of the power system in the southern region of Africa.	An integrated project with wind power in the Maputo grid and flood gates at Corumbana could be considered. It is recommended to further clarify and quantify the value of the potential wind power.
6)	100 MW of wind power can easily be installed and integrated in the Maputo grid.	It is recommended to confirm that areas are present and available for in total 100 MW wind power along the coastline between South Africa and Inhambane.
7)	Crane capacities of 120 ton / 66 m are available in Maputo (2006).	It is recommended to base a grid connected wind power development in Mozambique on wind turbine units sizes around 1 MW (height 50 m, weight of heaviest component 40 ton).
8)	The design wind speed in Mozambique is expected to be relative low. Wind turbine types designed and optimised for low wind operation are expected to be most economic feasible in Mozambique.	It is recommended to verify and quantify the design wind speed by continue the high quality wind measurements for additional 2-3 years at one of the sites.
9)	EdM have experiences with IPP and PPA, but for well known technologies. Wind power is a new technology in Mozambique where knowledge has to be established.	It is recommended that EdM will be the owner and operator of the first grid connected wind farm in Mozambique.
10)	Wind power capacity may be established within two years, and is a quick way to establish additional power generation capacity compared to thermal power plants or hydro power plants.	A pilot 10 MW wind farm at Chicumbane should be considered.

Executive summary in Portuguese

(to be prepared by Ministry of Energy)

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Abbreviations

DNER	Directorate of New and Renewable Energies
EdM	Electricidade de Moçambique
RISO	Risø National Laboratory

1 Introduction

The present Project *'Support for Wind Power Development in Mozambique - A study of the feasibility of wind power in the southern Mozambique'* has been executed in the period Oct 2006 to Apr 2008 by DNER, assisted by, Risø National Laboratory, Denmark, as Technical Consultant and supported by Danida, Denmark.

The Mozambique power system is closely connected to the power systems in the rest of the southern Africa, dominated by Eskom, South Africa, with current lack of power generation capacity and with a power generation dominated by thermal coal generation.

The power system in Mozambique, operated by EdM, is split into the northern part with excess power generation – mainly hydro power – and the southern part, the Maputo power system, with lack of power generation. The two parts are presently only interconnected by power lines via South Africa. Mozambique is net exporter of electricity (to the southern Africa), while the Maputo Region is net importer of electricity with two dominating load centres: Maputo and the Mozal aluminium factory.

With the present and expected energy prices, wind power is competitive to other power generation technologies in areas with good wind resources. However, there is a lack of information of the actual wind resources in Mozambique. The main focus of the Project has therefore been to establish information of the wind resources.

The value of wind power depends on how the wind power can be integrated in the Maputo power system, which alternative generation the wind power will substitute (if any), if the wind power can substitute alternative generation capacity (its capacity value), and of the value of the additional electricity (if any). The value of the wind power includes

- support to the limited power generation capacity in the Maputo power system;
- support to the current lack of power generation capacity in the interconnected southern Africa power systems;
- support to sustainable power generation in the southern Africa.

The project has focused on the southern part of Mozambique along the coastline where the best wind resources are expected, where the power is most needed and where the highest value of the wind power is expected. High quality wind data have been collected for one year at two selected sites as part of the Project.

The Project was finalised with a workshop in March 2008 with invited stakeholders, presenting and discussing the findings and the recommendations.

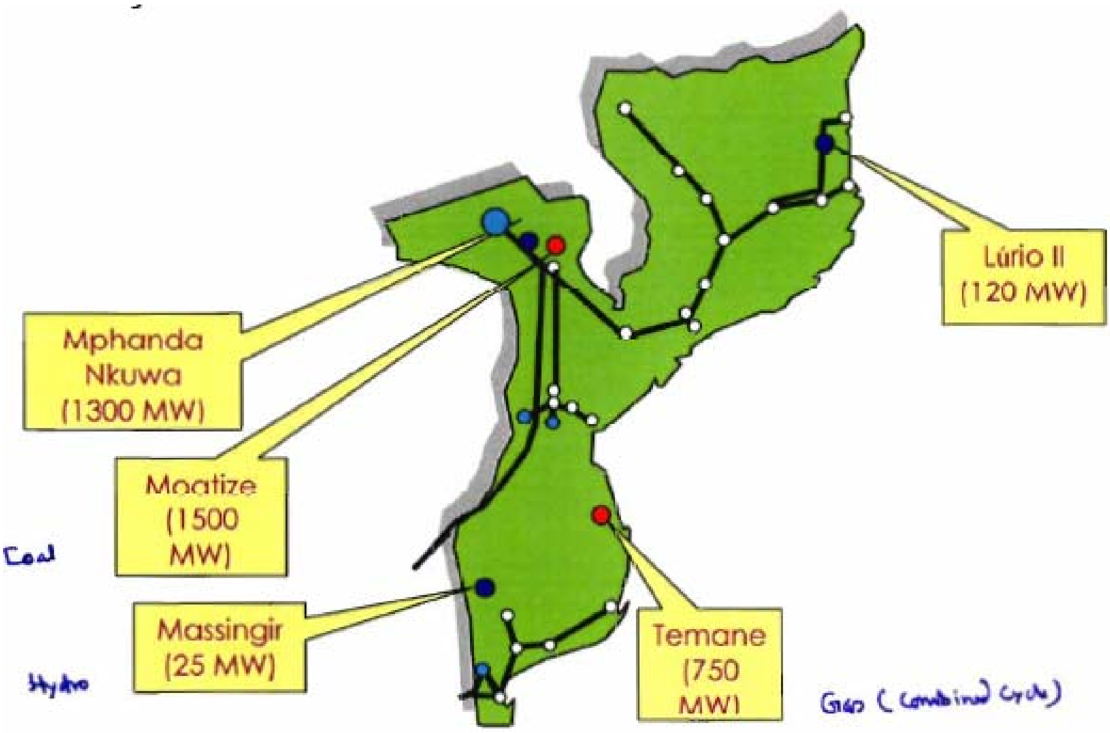

Figure 1: Overview of the power system in Mozambique and the planned new power plants. (Source: EdM, 2008)

2 The power supply in Mozambique

The power system in Mozambique is split into the northern system and the southern system, at present only interconnected by transmission lines via South Africa. National interconnection line is considered between the northern part and the southern part of the power system. A development plan for the power system is prepared as part of the Energy Reform & Access Project (funded by the World Bank).

The main generation is in the northern system, dominated by the 2000 MW Cahora Bassa hydro power plant, while the main consumption is in the southern system, dominated by the Mozal aluminium factory (900..1000 MW constant load) and the Maputo urban area (200 MW).

The power system is closely connected to the power system in the southern Africa, dominated by the South Africa based ESCOM power company.

The main power generation in Mozambique is hydro based. Mozambique also has natural gas resources. Most of the power generation (80 %) and gas in Mozambique is exported to South Africa. Part of the power export is imported back onto the South

	Variable cost	Capacity charge	Fixed charge
	Mt/kWh	Annual Mt/MW	Annual Mt
Low voltage	2 015	95 737	187 285
Medium voltage	1 034	118 034	879 096
High voltage	922	107 159	879 096

Table 1: Proposed large consumer tariffs. (Source: Reference [1])

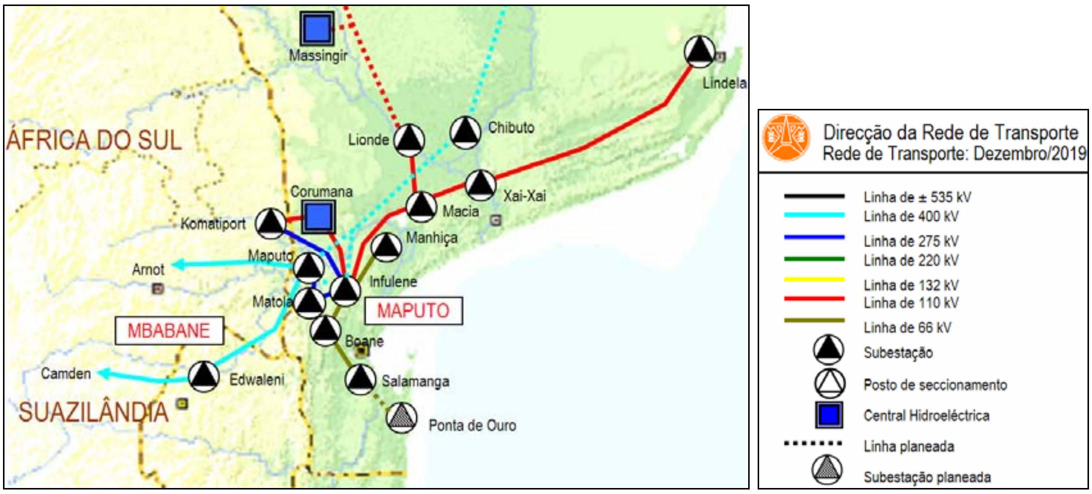

Figure 2: The power transmission lines in the EdM South Region. (Source: EdM)

grid, in particular for the Mozal aluminium plant.

New power plans are in the pipeline – see Figure 1 – which may facilitate the establishment of a national interconnection of the northern and the southern power systems.

Electricity energy balance figures (2001) for the EdM area is given in Table 2 with a total annual energy balance around 1500 GWh.

Proposed electricity tariffs for large consumers are given in Table 1.

	Southern Region GWh	Mozambique GWh
Own generation	x	300
Imports	x	33
Purchases	x	1134
Total energy	**x**	**1467**
Power station losses	x	96
Transmission losses	x	135
Export	x	0
Gross available	**x**	**1237**
Public lightning	x	28
EdM consumption	x	16
Distribution losses	x	129
Invoiced energy	**x**	**1065**
Peak demand (MW)	x	223
Load factor	x	0.71

Table 2: Electricity energy balance within the area of EdM in 2001. (Source: [1])

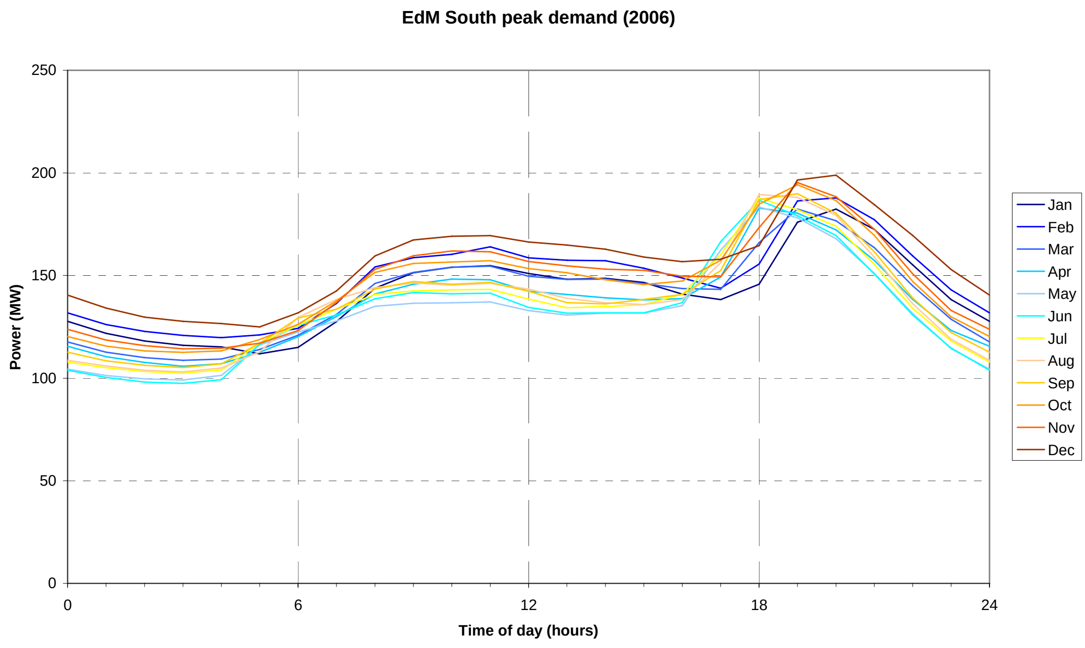

Figure 3: EdM South Region daily load profile (exclusive Mozal) in terms of monthly average peak power on hourly basis - 2006. (Source: EdM)

2.1 EdM South Region (Maputo)

The Maputo power system (EdM South Region) is illustrated in Figure 2, with 400 kV power lines to South Africa, a 110 kV power line to Inhambane (Lindela substation) and a 66 kV power line to Salamanga. In addition, a proposed new 100 kV national interconnection line is indicated, passing the planned 25 MW Massingir

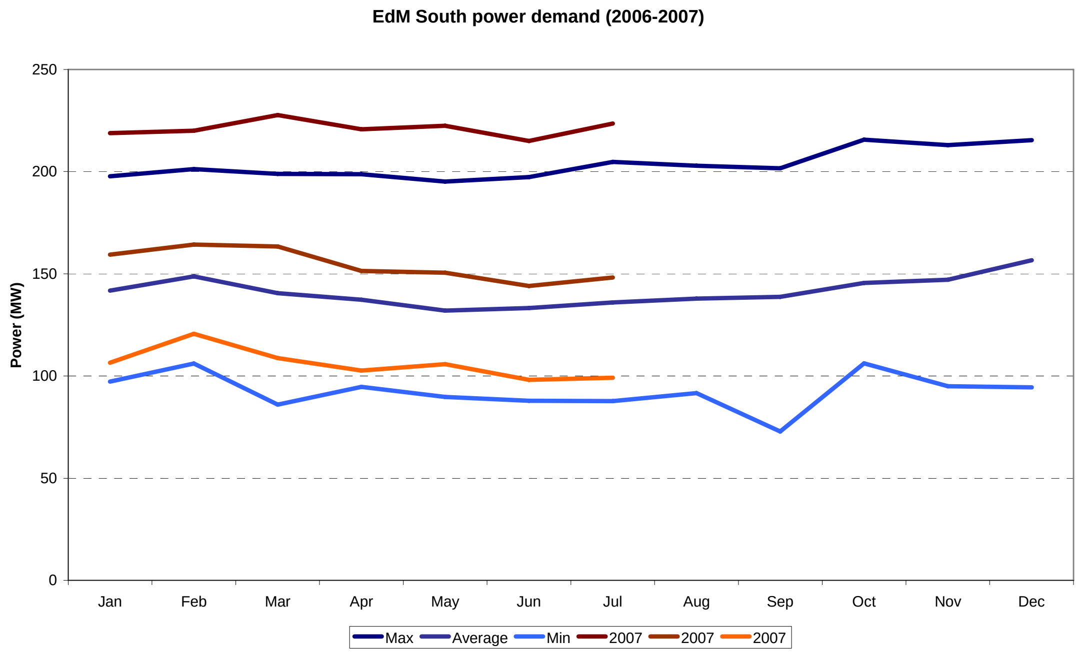

Figure 4: EdM South Region seasonal load profile on monthly basis (exclusive Mozal) in terms of monthly maximum, average and minimum demand – 2006 and 2007. (Source: EdM)

hydro power plant.

The Maputo power system is characterised by its limited (hydro based) local generation capacity, its dependency on the strong grid connection to South Africa, a single dominating consumer – the 1000 MW Mozal aluminium factory – and the Maputo main load centre.

There is one hydro power plant in the region (Corumana, 16 MW), and another is in preparation (Massingir, 25 MW) (when?).

Daily load profiles for EdM South Region (exclusive Mozal) are illustrated in Figure 3 for each month in 2006 in terms of the monthly average load for each hour during the day. The daily load profile has a typical minimum load during the night and a maximum peak during the evening. The monthly average hourly load varied in 2006 between 100 and 200 MW, with the minimum in June during the night and the maximum in December during the evening.

The seasonal variations of the minimum, average and maximum loads for the EdM South Region (exclusive Mozal) are illustrated in Figure 4 for each month in 2006 and part of 2007. The seasonal variations are small and in the same scale as the annual growth. In the future, the minimum load is expected to be higher than 100 MW. This number is important for integration of wind power.

(Numbers are missing)

Figure 6: EdM South Region load development on annual basis. (Source: ???)

As the wind farm proposed by the Project – until the very last Project Mission – was expected to be connected to the Salamanga power substation, this substation is described in more details in the section below.

As the value of the wind power may depend on the coordinated operation of the wind and the hydro, the Corumana hydro power plant is also further described in a section below.

Figure 5: The 40 m communication mast at the Salamanga substation suitable for wind measurement instrumentation. View towards east. (Photo: Riso, 2006)

Figure 7: The 10 MVA transformer at the EdM Salamanga power substation. (Photo: Riso, 2006)

2.2 Salamanga power substation

The Salamanga power substation was installed in 2002. It is located 50 km south of Maputo, 30 km north of Ponta de Ouro and 15 km from the sea. The substation is connected to the Maputo power system through a 66 kV power line. The short-circuit level at the substation is 50..100 MVA. A 33 kV power line to Ponta de Ouro is connected via a 10 MVA / 66/33 kV transformer. The substation is prepared for extension with more transformers – see Figure 7. A 10 MW wind farm could easily be connected to this substation.

A 40 m communication mast exists at the Salamanga substation area (Figure 5), suitable for wind measurement instrumentation. If the mast is instrumented with automatic wind measurement equipment, these wind data could be used to evaluate the expected reduction of the wind resources inland, compared to the wind resources along the coastline (represented by the wind data from the Ponta de Ouro site).

2.3 Xai-Xai power substation

The Xia-Xia power substation at the 110 kV power line between Maputo and Lindela (Inhambane) is located next to the proposed Chicumbane wind farm site. A 10 kW wind farm can easily be connected at the substation with spare space for an additional transformer – see Figure 9.

2.4 Corumana hydro power plant

The Corumana Dam and hydro power plant was established in 1989 with the two-folded objective to regulate the water for irrigation of the down-stream farmland and to produce power. The 16 MW Corumana hydro power plant is presently the only

Figure 9: Xai-Xai 110 kV substation. (Photo: Riso, 2008)

hydro power plant in the EdM South Region. The Corumana power plant is connected to the Maputo power system through a 110 kV power line. Another 110 kV power line goes to South Africa.

The water inflow to the Corumana Dam is rather limited and the power plant can not be operated on full power all time. At the time of visit, the power station were operated only 4 hours a day during peak load time (Monday to Saturday, 17 to 21) and only at 9 MW. The water inflow is 550 mio m3/y in average, corresponding to 10 GWh/y hydro power generation. The water inflow change a lot from year to year – see Figure 10. The present capacity of the Corumana dam is 880 mio m2 (@ water level 111 m asl, covering an area of 71 km2) – corresponding to 25 GWh hydro power generation. The minimum water level for power generation is 95 m – corresponding to 150 mio m2 water volume.

The dive is prepared for installation of flood-gates (see Figure 8), which will increase the capacity of the dam by 40 % to 1400 mio m2 (@ water level 117 m, covering an area of 91 km2). The expected results of the extended water storage capacity by the introduction of flood gates (and an extra dive to prevent overflow) is an increase in the firm energy generation from 10 to 15 GWh/y and in the total energy production capacity from 25 to 30 GWh/y. The cost is estimated at USD 20 mio – inclusive a necessary additional dive [2].

Figure 8: The overflow apertures at the Corumana dike, prepared for flood gates. (Photo: Riso, 2007)

Figure 11: Intake for the Corumana hydro power plant at water level 100 m asl. (Photo: Riso, 2007)

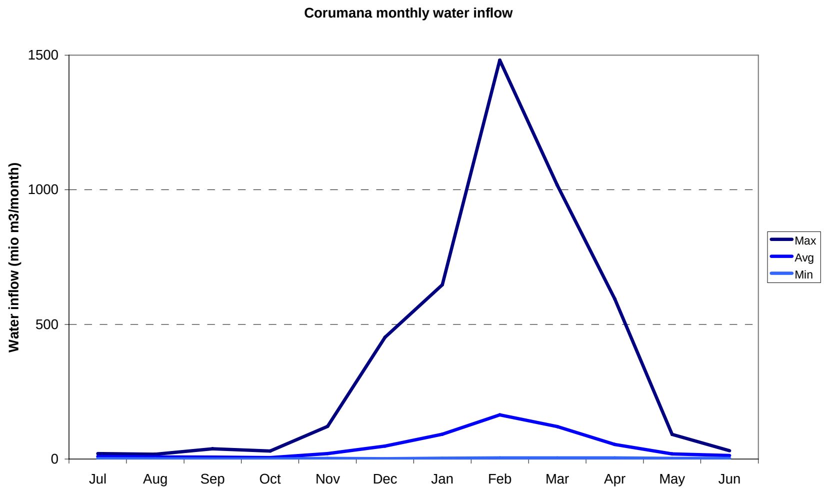

Figure 10: Monthly water inflow to Corumana Dam. (Source: Reference [2])

Level	Volume	Area	Firm energy	Total energy
m	mio m3	km2	GWh/y	GWh/y
111	880	71	10.1	25.4
117	1375	91	14.9	30.4
Increase				

Table 3: Characteristics of Corumana Dam. (Data source: Ref [2])

3 Wind resource assessment

The wind resources in Mozambique have been assessed and estimated based on information from various sources, including data from a global meteorological database, data from meteorological stations in Mozambique, wind data from airports meteorological station and dedicated measurements.

The project covers only the southern part of Mozambique, and only sites close to the sea. The estimation of the wind resources along the coast from the border of South Africa to Ihhambane is based on one year of high quality wind data collected as part of the present project at two sites close to the sea – at Ponta do Ouro and at Tofinho – in combination with 10 years of monthly wind data from Maputo Airport.

3.1 NCEP-NCAR

Based on information from the NCEP/NCAR global meteorological database[1], the best wind resources in Mozambique are expected in the southern part of Mozambique close to the sea – see Figure 12 and Figure 13. The Project decided to focus the wind resource assessment at the coastline from the border of South Africa to Inhambane.

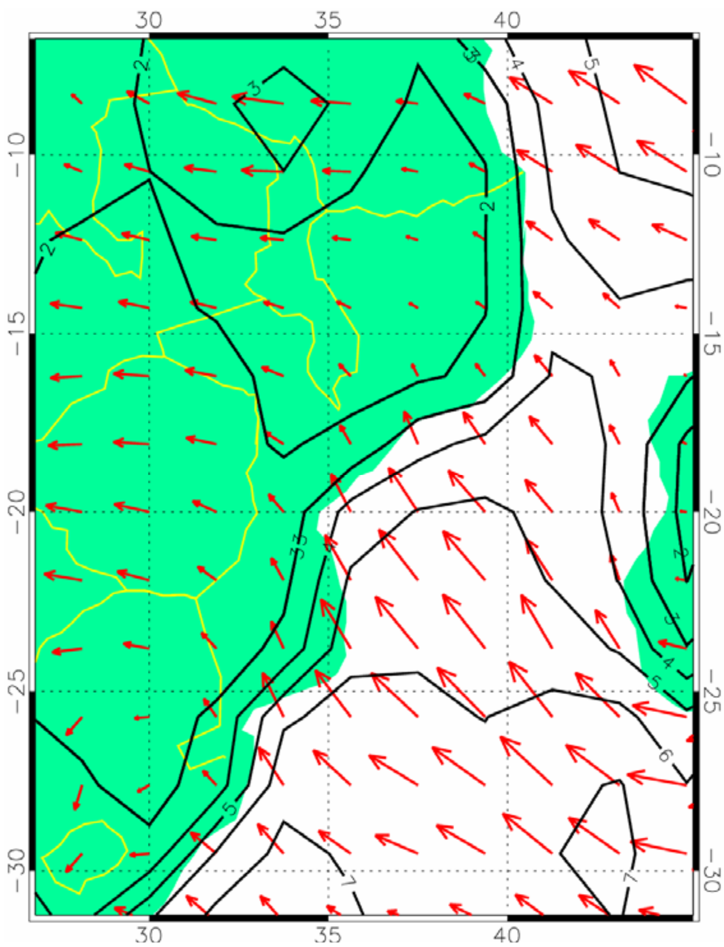

Figure 12: Mean wind speed contours lines and mean wind vectors at 10 m a.g.l. at 200×200 km grid points covering Mozambique based on 30 years data (1976-2005) from NCEP/NCAR reanalysis database. (Source: Riso)

[1] NCEP/NCAR reanalysis database...

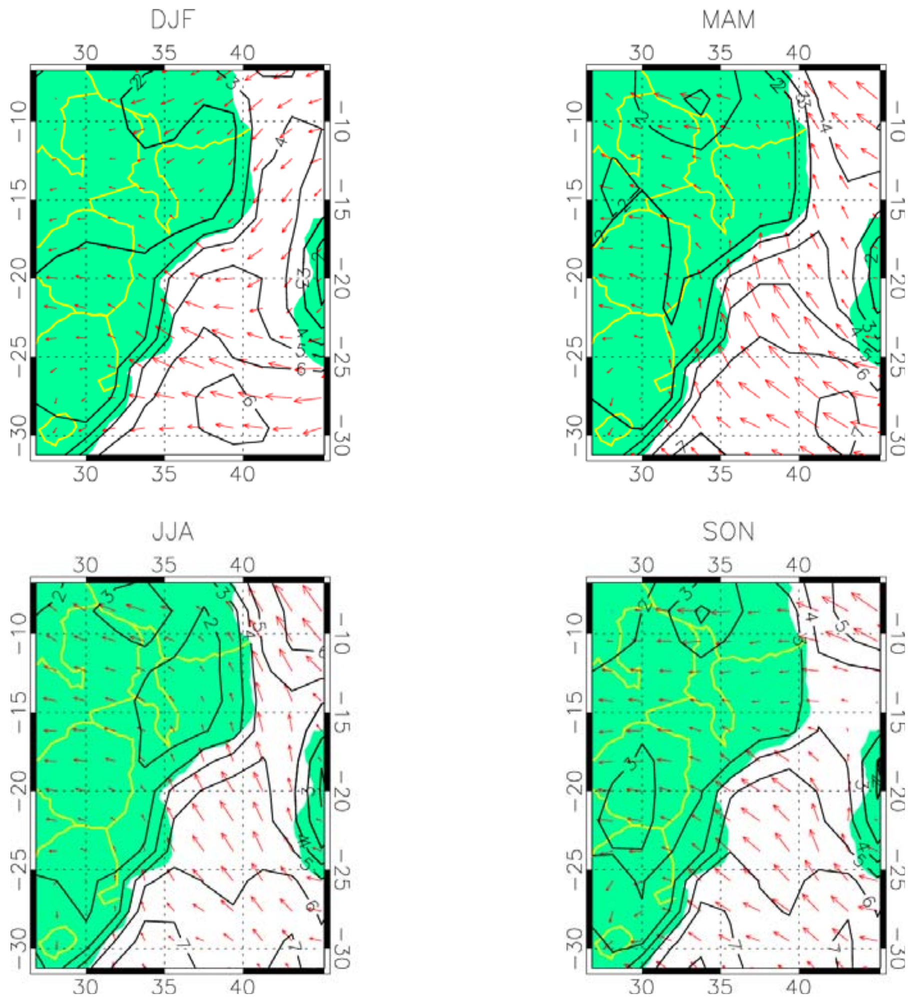

Figure 13: The seasonal variations of the wind speed in Figure 12. (Source: Riso)

3.2 INAM

The National Meteorological Institute, INAM (Instituto National de Meteorologia), operates several meteorological stations, distribute across Mozambique. Wind parameters are typically measured on top of the office building, in the middle of a town, surrounded by buildings and trees.
The data are typically recorded on paper charts (like the one illustrated in Figure 14). The charts are manually read, and the numbers for every 4or 6 hours noted in a paper form. The wind data recorders at Maputo and Inhambana Meteorological Offices were out of operation during the time of the Project.

Figure 14: The wind data paper chart recorder at Inhambane Meteorological Office. (Photo: Riso)

INAM's Meteorological Office in Inhambana (Figure 15) is typical, with the building in the middle of the town and with the wind speed instruments placed on the top of the building. However, the

Figure 16: Maputo Met Office. (Photo: Riso, 2006)

stations wind recorder has been out of operation during the project period, and therefore no correlation can be made to the wind data measured as part of the project.

Annual average wind speed data collected since 1950 at four of the INAM Meteorological Stations (Maputo, Lichinga, Pemba and Changalane) are indicated by the plot in Figure 17. The locations of the stations are indicated at the map in Figure 18. The following observations can be made from the plot:

- The wind speed levels recorded are very low – 5..15 km/h (corresponding to 1..4 m/s). Properly because the instruments does not measure the free wind.
- The highest wind speed level is recorded at Lichinga. However, the differences in level are not necessarily representative for the wind resources, but express rather different measuring conditions.
- The Pemba curve shows a significant shift in the level around year 1995. Properly because the instrumentation has been changed or moved.
- The Changalane curve shows a decreasing trend during the period. Properly because trees has grown up around the instruments.

These meteorological stations are not designed to provide accurate information of the wind resources. The data is for very little use in the present project.

Figure 15: The Met Office in Inhambane and the view from the top of the building (at the cup anemometer) towards SE. (Photo: Riso and Claus Lewinsky, 2007)

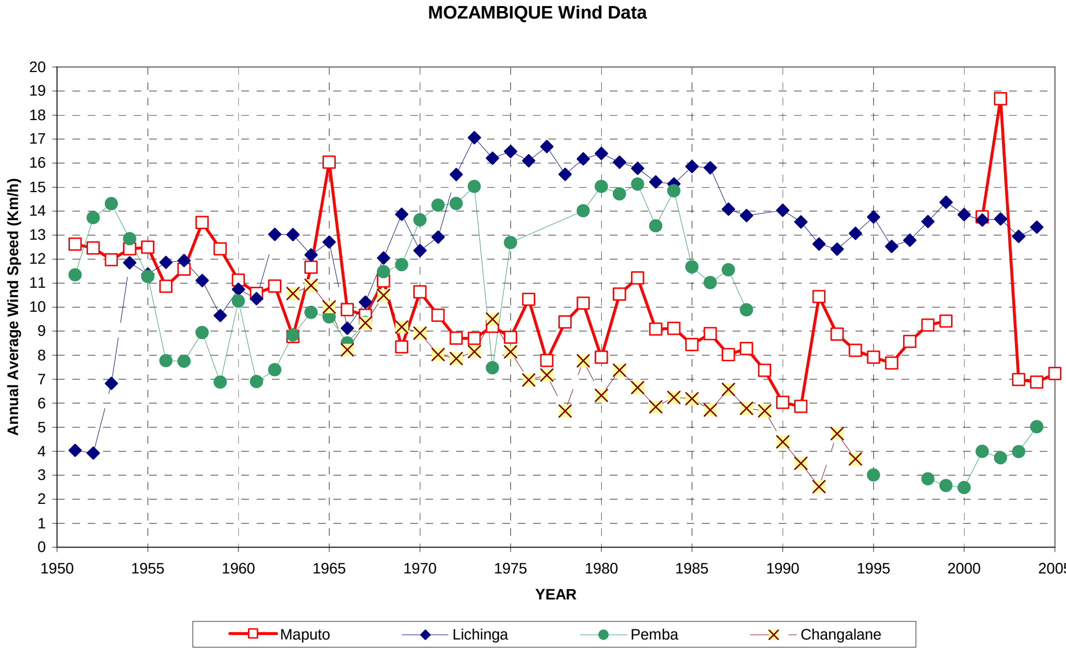

Figure 17: Wind data from four meteorological stations in Mozambique. Annual average wind speed (in km/h). (Source: INAM)

Figure 18: The location of the meteorological stations of Figure 17. (Map source: Google)

Figure 19: The met-mast at Maputo Airport, operated by INAM. (Photo: Riso)

3.2.1 Maputo Airport

INAM has operated an automatic weather station at the Maputo Airport at the run-way area since 1999 (Figure 19). The airport is approximately 2 km inland from the sea. The UTM coordinates for the station has been measured as N-2 867 205m; E457 193m (Z 36). The wind speed is measured at 12 m height agl. Monthly average wind speed data from this station has been provided by INAM to the Project. These wind data have been used as the long term reference for the wind data collected at Ponta de Ouro and at Tofinho.

The annual minimum, average and maximum monthly average wind speed values observed from the mast are indicated by the time plot in Figure 20. The plot clearly illustrates the variations from year to year.

The monthly average wind power values ($0.5 \times w^3$; w: wind speed) for the 9 years period with wind data from Maputo Airport are illustrated in Figure 21 together with

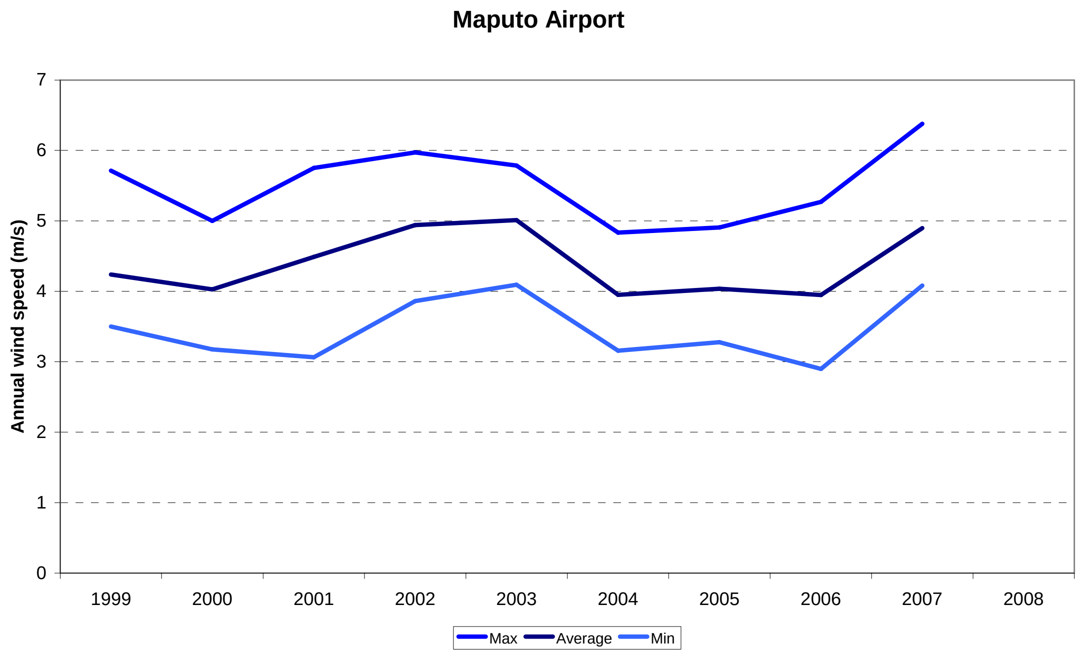

Figure 20: The annual minimum, average and maximum monthly average wind speeds observed at the INAM 12 m met-mast at Maputo Airport in Figure 19. (Data source: INAM)

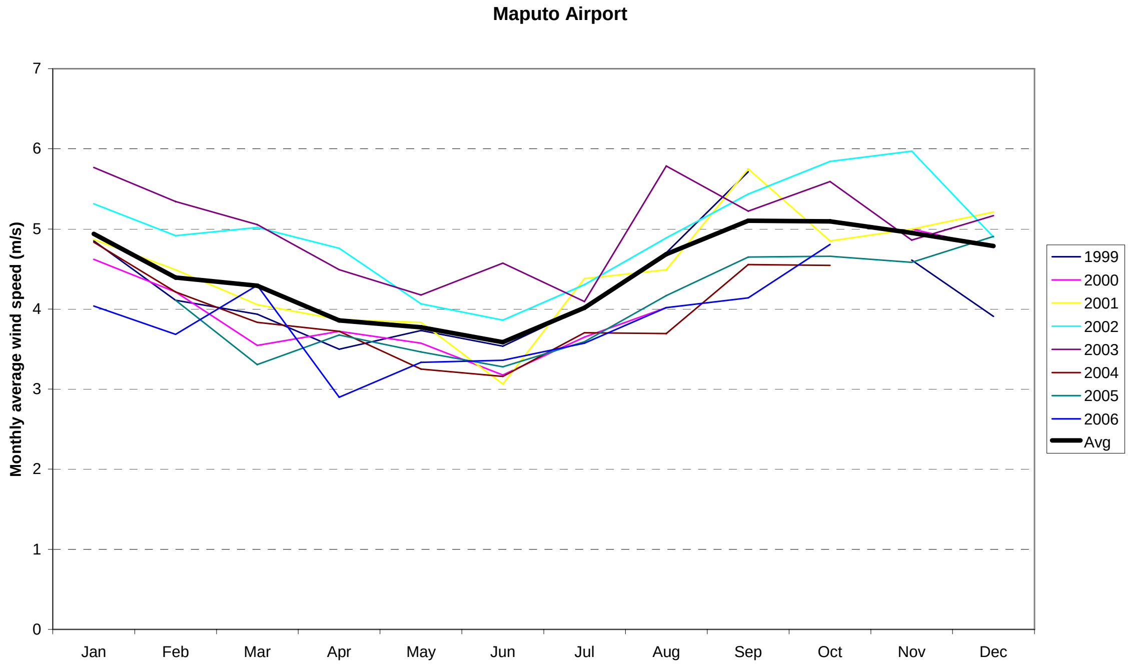

Figure 22: Monthly average wind speed measured at the INAM 12 m met-mast at Maputo Airport. (Data source: INAM)

the average wind power for the full period (47 W/m^2) and the average wind power in the period with wind data from Ponta de Ouro and Tofinho (Mar 2007 – Mar 2008) (55 W/m^2) – 10 % higher than the average. The measured data are therefore not expected to be long term representative, and the calculated production numbers should be reduced by 10 %.

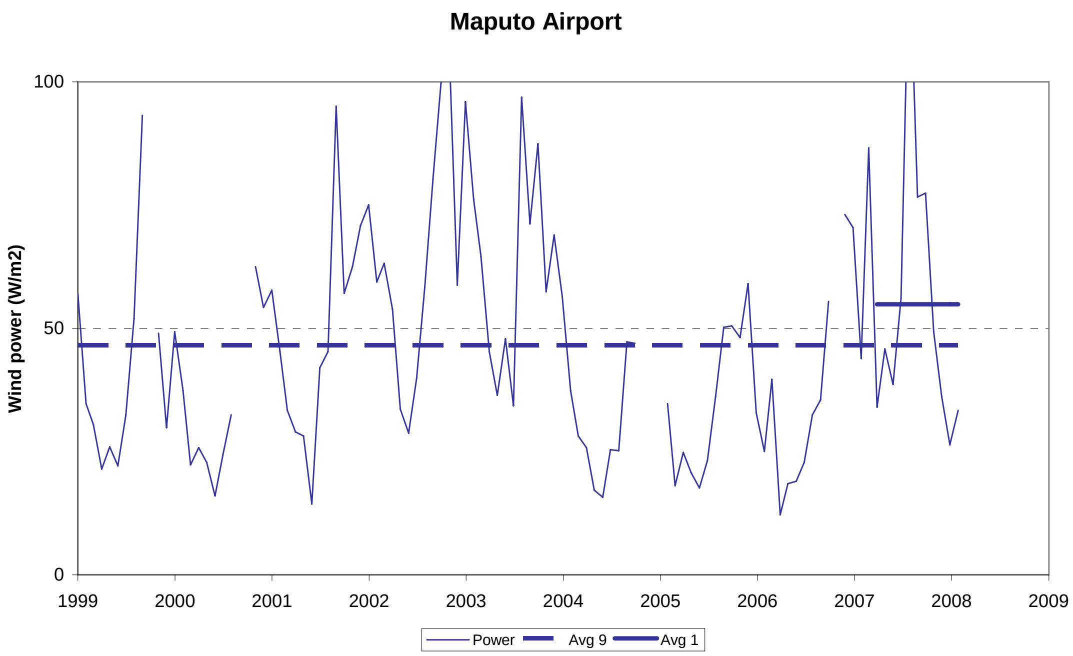

Figure 21: Maputo Airport wind power data (0.5×w^3) – time series plot of 9 years monthly average values with indication of the 9-years average (dotted line) and the average for the 1 year period with wind data from Ponta de Ouro and Tofinho. (Data source: INAM)

3.3 Wind data analyses

As part of the present Project, two complete NRG wind measuring systems with 30 m masts and automatic electronic data loggers have been provided, installed and operated by DNER. Wind data have been measured and collected from the two masts for one year at Ponta do Ouro and Tofinho.

The data are collected by DNER, visiting the stations once a month. Access to the Ponta de Ouro site is difficult and requires a full day, even if the site is less than 100 km south of Maputo. The local staff in Inhambane downloads the data from the logger, but there have been problems in transferring the data from Inhambane to Maputo, and the DNER staff in Maputo decided to go to Inhambane to collect the data. The distance between Maputo and Inhambane is 500 km, and it is a two day trip. The NRG data logger use ordinary memory cards for the data storage. The Consultant recommends investing in 10 memory cards to be placed in Inhambane, and after downloading the data, the local staff in Inhambane can send the memory cards with data by ordinary mail to Maputo.

The wind data analyses are based on 1 year of detailed high quality data from these masts, and 9 years of monthly average wind speed from Maputo Airport.

The sites for the two Project met-masts have been evaluated and selected based the following criteria:

- Exposed by the free wind from the sea (from E to S)
- Space for erection of the met-mast
- Site accessibility
- Land availability
- Wind farm potential in the area, but not necessarily where the mast is erected

The evaluation criteria for the wind farm potential in the area include:

- Power grid accessibility
- Power transmission line capacity
- The value of the wind power for the power supply system

The following sites have been inspected:

- Two sites north of Ponta do Ouro
- Four sites east of Inhambane
- Lichinga

See appendix ??? for further information.

At the two Project met-stations the following parameters have been measured and recorded:

29 m:	Wind speed	Wind direction
20 m:	Wind speed	Wind direction
10 m:	Wind speed	
5 m:	Temperature	

Figure 23: DNER staff collecting data from one of the NRG data loggers at the met-masts. (Photo: Riso, 2007)

Figure 25: Ponta do Ouro met-mast, seen towards E. (Photo: Riso, 2007)

For each of the parameters the average value, the standard deviation, the minimum value and the maximum value within the 10 minutes periods are recorded every 10 minutes – in total 24 values every 10 minutes or 3456 numbers per day, or over one million per year.

A cyclone passing Tofinho / Inhambane in the beginning of 2007 has been reported, but no specific information has been found.

3.4 Ponta do Ouro

The Ponta de Ouro site is situated less than 100 km south of Maputo, 500 m inland from the coastline in an area with dunes with low vegetation.

A 30 m NRG met-mast was installed at the Ponta do Ouro site in March 2007 by DNER, with assistance from the Technical Consultant. The station is owned and operated by DNER. Wind data has been recorded and collected since 17 March 2007.

The topology and the surface characteristics of the Ponta do Ouro site are illustrated by the photos in Figure 25 and Figure 24.

The topography of the Tofinho area is indicated in 3D map in Figure 26 and the

Figure 24: Ponta do Ouro site towards N. (Photo: Riso, 2006)

UTM coordinates (Zone):	N -2956880 m E 489610 m
Elevation:	30 m
Distance from sea:	500 m

Table 4: The location of the Ponta do Ouro met-mast.

WAsP map in Figure 27

The time series for the full period of the 10-minutes values of all the parameters recorded are show by the plots in Figure 28. The wind speed sensor at 20 m height level was working on-and-off for a period of one month in Jun-Jul 2007. The actual problem was never identified.

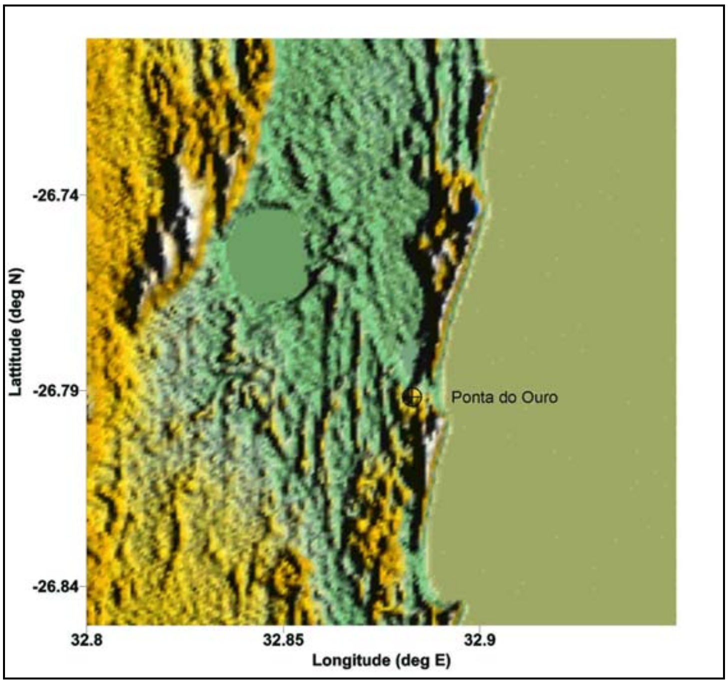

Figure 26: 3D map with Lat-Long coordinates of the Ponta do Ouro area. (Data source: SRTM)

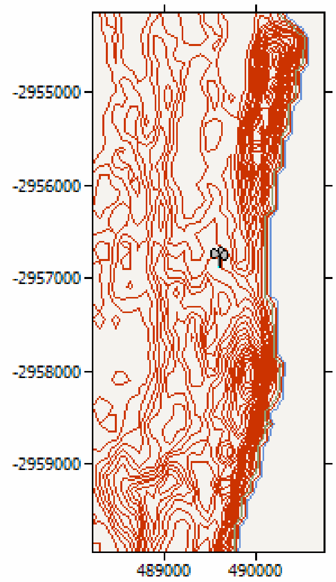

Figure 27: WAsP map with UTM coordinates (Zone 36) and 5 m height contour lines of the Ponta do Ouro area. (Source: Riso)

The vertical wind speed profile is illustrated by the plot in Figure 30. The plot also provides a check of the quality of the data collected. The wind speed sensor at 20 m height level has been out of operation for a period, indicated by the red dots in the bottom of the plot. Except from this, the data shows a good correlation between the wind speeds recorded at the three height levels, indicating high quality of the data. The linear fits indicate that the wind speeds recorded at 10 m and 20 m height levels are equal, but approximately 10 % lower than wind speed at 29 m level. This indicates a terrain speed up effect, most effective at 10 m height level.

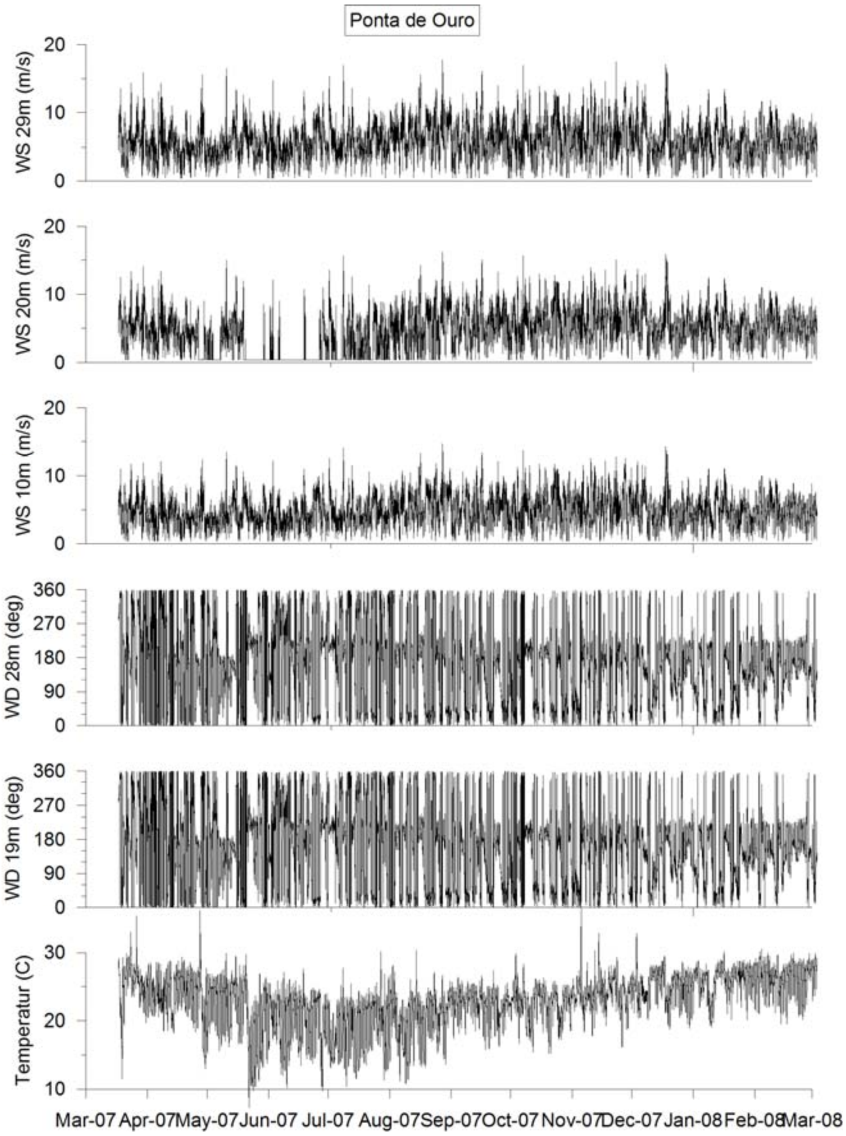

Figure 28: Time series plot of the 10 minutes average values of the data collected at Ponta de Ouro in the period 17Mar07 to 4Mar08.

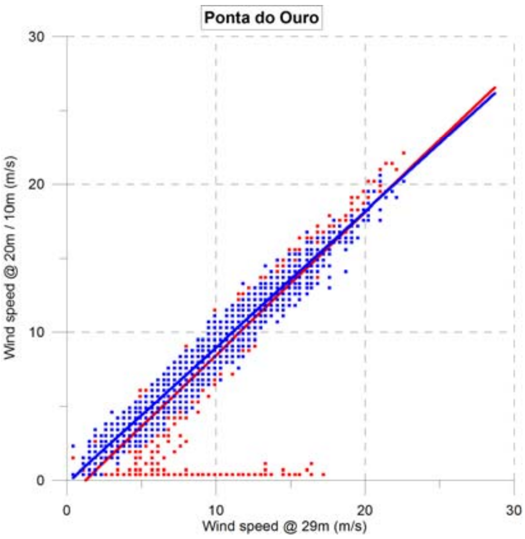

Figure 30: Plot of the correlation between 10 minutes average wind speeds recorded simultaneously at 29 m (x-axis), 20 m (red) and 10 m (blue) height levels at the Ponta do Ouro met-mast. The dots represent individual data sets. The lines represent linear curve fits. The wind speed sensor at 20 m level has been out of operation for a period. (Source: Roso)

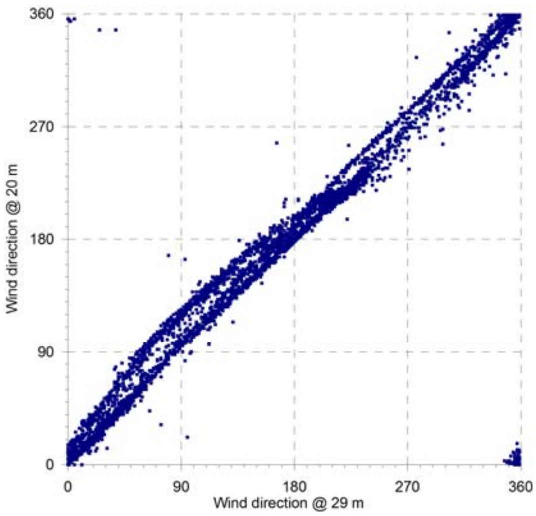

Figure 29: Plot of the correlation between simultaneously 10 minutes average of the wind direction data at 29 m (x-axis) and 20 m (y-axis) height levels at Ponta do Ouro for the period 2007-03-17 to 2008-03-03. (Source: Riso)

The correlations between simultaneous 10-minutes average values of the wind direction observed at 20 m and 29 m height levels are indicated by the plot in Figure 29. The plot demonstrates a good correlation and a high quality of the data. The plot indicates a general change of the wind direction with the height for wind coming from east – a 10..30 degrees shift from 20 m to 29 m height levels. The plot also clearly indicates specific correlations for different conditions – properly for different atmospheric stability conditions during the day.

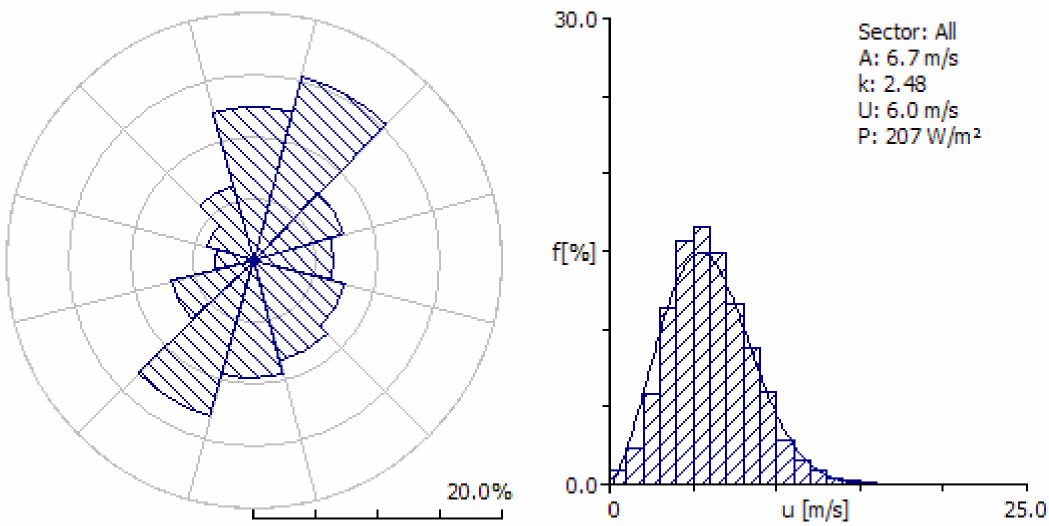

Figure 31: Ponta de Ouro statistics - graphical presentation of the statistical analyses of the wind direction (the wind rose) and the wind speed (the histogram) at 29 m height level of the data in Figure 28.

Mean wind speed:	6.0	m/s	
Mean power density (@ air density 1.225 kg/m3):	210	W/m2	
Weibull fit parameters (A; k):	6.7	m/s;	2.5
Max wind speed (10 min avg / gust):	18	m/s	29 m/s

Table 5: Key characteristics of the wind speed measured at Ponta do Ouro at 29 m height level.

The key characteristics from statistical analysis of the wind measured at 29 m height level are presented in Table 5. Results from statistical analyses of the 10-minutes values of the wind speed and the wind direction observed at 29 m height level are presented in graphical form in Figure 31. The wind rose of the wind direction data indicates two prevailing wind directions – NNE and SSW. Only minor part of the wind is coming from the sea (E). A Weibull distribution (the smooth graph), used in the WAsP modelling of the wind resources, fits well to the observed distribution (the histogram) of the wind speed.

3.5 Tofinho

The Tofinho site is located east of Inhambana, 500 km north of Maputo, at an open tip close to the sea, very well exposed by the free wind from the sea in a sector from north over east to south.

A 30 m NRG met-mast was installed at the Tofinho site in March 2007 by DNER, with assistance from the Technical Consultant. The station is owned and operated by DNER. Wind data has been recorded and collected since 20 March 2007. Key characteristics of a statistical analysis of the data are given in Table 7.

The met-mast and the surface characteristics of the Tofo site are illustrated by the photo in Figure 32.

The time series for the full period of the 10-minutes values of all the parameters recorded are show by the plots in Figure 35.

The vertical wind speed profile is illustrated by the plot in Figure 36. The plot also provides a check of the quality of the data collected. The data shows a good correlation between the wind speeds recorded at the three height levels, indicating high quality of the data. The linear fits indicate that the wind speeds recorded at 10 m, 20 m and 29 m height levels are almost equal. This confirms an expected speed up effect caused by the terrain, effective up to at least 20 m height level.

Coordinates:	UTM Zone ?? N -2641870 m; E 760090 m	LL 35.55°E; 23.86°S
Elevation:	30 m	
Distance to sea:	150 m	

Table 6: The location of the Tofinho met-mast.

Figure 32: Tofinho met-mast site towards SE. (Photo: Riso, 2007)

The correlation between simultaneously 10-minutes average values of the wind direction observed at 20 m and 29 m height levels is indicated by the plot in Figure 37. The plot demonstrates a very good correlation with almost no change in wind direction with the height, indicating high quality of the data.

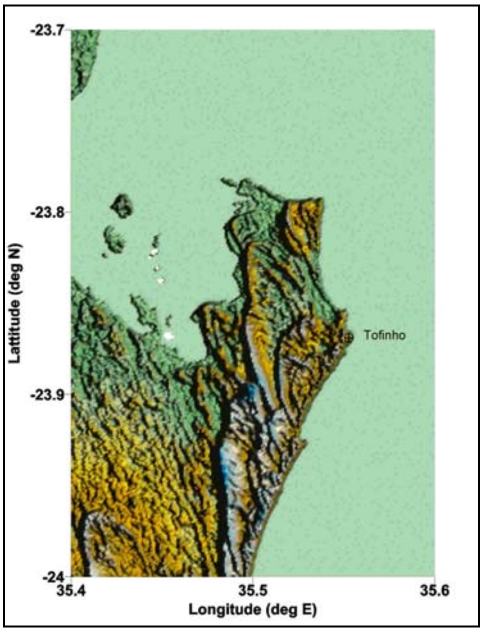

Figure 33: 3D map with Lat-Long coordinates of the Tofinho area, indicating the topography based on the SRMT database. (Source: Riso)

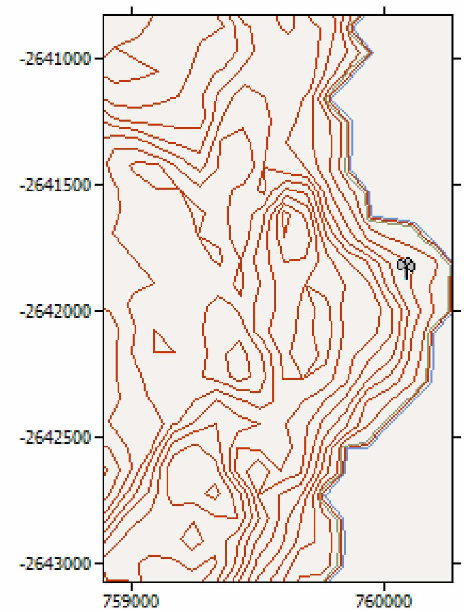

Figure 34: WAsP map in UTM coordinates (Zone 36) of the Tofinho area with 5 m height contour lines. (Source: Riso)

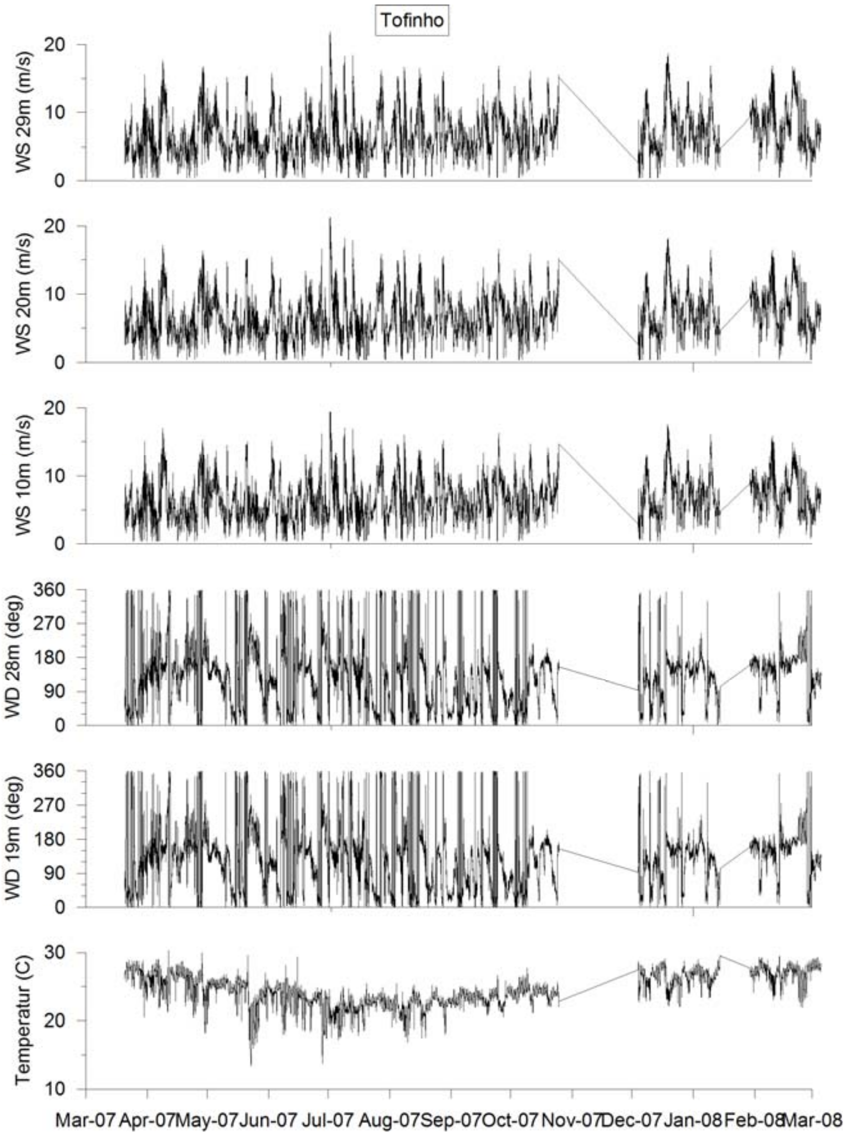

Figure 35: Tofinho time series plots of the 10 minutes average data collected in the period 20Mar07 to 07Mar07.

The topography of the Tofinho area is indicated in 3D map in Figure 33 and the WAsP map in Figure 34.

The key characteristics from statistical analysis of the wind measured at 29 m height level are presented in Table 7.

Mean wind speed:	7.0	m/s		
Mean power density (@ air density 1.225 kg/m3):	350	W/m2		
Weibull fit parameters (A; k):	7.7	m/s	2.1	
Max wind speed (10 min avg / gust):	22	m/s	26 m/s	

Table 7: Tofinho key characteristics of the wind speed measured at 29 m height level.

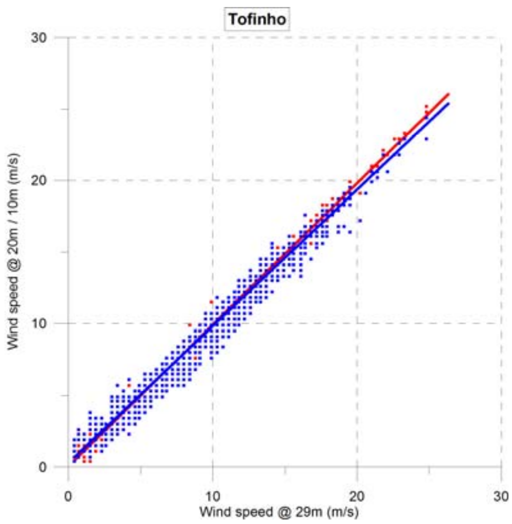

Figure 36: Plot of the correlation between 10 minutes average wind speeds recorded simultaneously at 29 m (x-axis), 20 m (red) and 10 m (blue) height levels at the Tofinho met-mast. The dots represent individual data sets. The lines represent the linear curve fits. (Source: Roso)

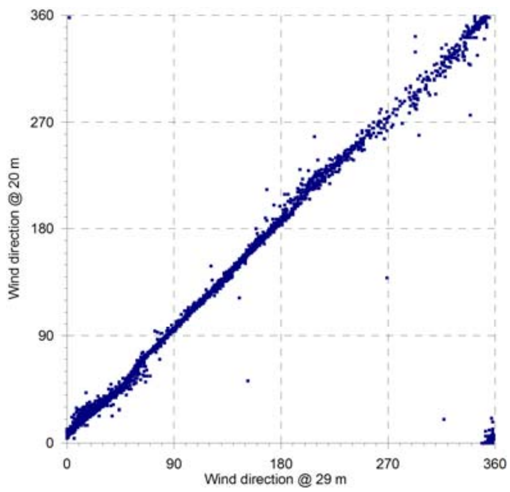

Figure 37: Plot of the correlation between simultaneously 10 minutes average of the wind direction data at 29 m (x-axis) and 20 m (y-axis) height levels at Tofinho for the period 2007-03-20 to 2008-03-05. (Source: Riso)

Results from statistical analyses of the 10-minutes values of the wind speed and the wind direction observed at 29 m height level are presented in graphical form in Figure 38. The wind rose of the wind direction data indicates prevailing wind direction from SE. A Weibull distribution (the smooth graph), used in the WAsP modelling of the wind resources, fits well to the observed distribution (the histogram) of the wind speed at wind speeds >6 m/s. The deviations at 4..6 m/s will have a minor impact on the accuracy of the WAsP results.

The time plots in Figure 39 of two month of data indicate some, but no clear, correlation between the winds measured at Ponta de Ouro and Tofinho, respectively.

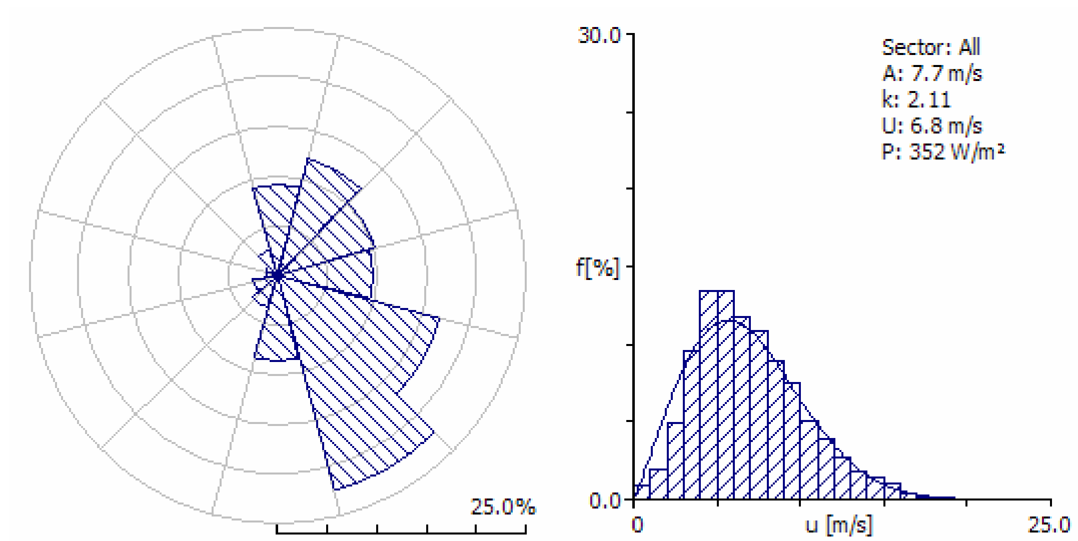

Figure 38: Tofinho wind statistics - graphical presentation of the statistical analyses of the wind direction (the wind rose) and the wind speed (the histogram) at 29 m height level of the data in Figure 35.

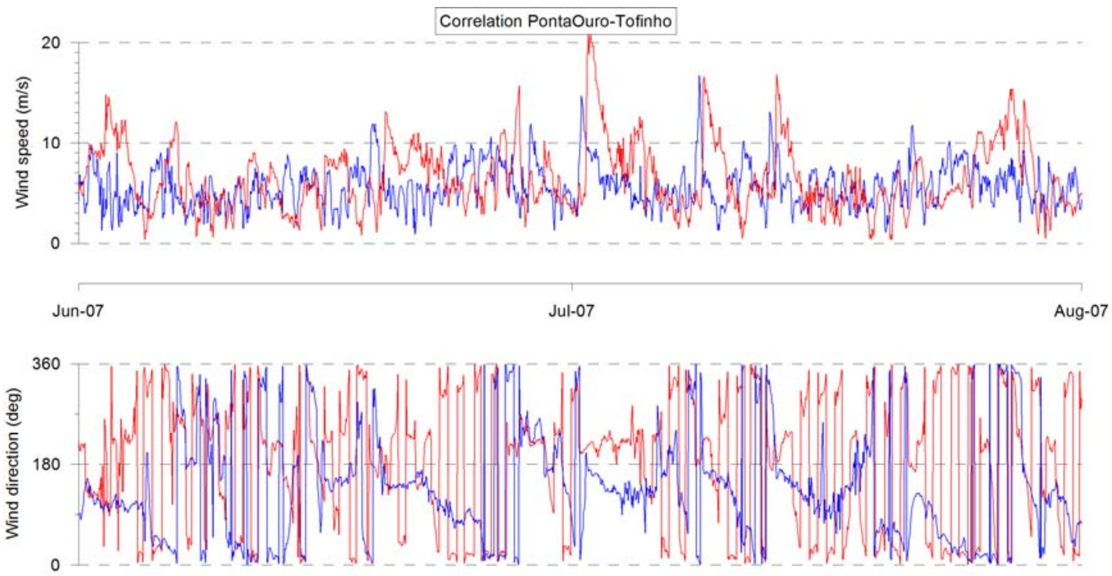

Figure 39: Time plots of two month of data (10 minutes average values for the period 070601-070801) from Ponta de Ouro (blue) and Tofinho (red) of wind speed and wind direction at 29 m height level.

3.6 Xai-Xai

At the very last Mission within this Project, the Jangamo site was identified, and information was provided from a previous study conducted by Carl Bro, Denmark. High quality wind data has not been collected at Jangamo as part of the present Project, but wind data are available from the nearby Xai-Xai Meteorological Station, provided by INAM (as part of a study in 2004[2]). The station has not been inspected as part of the present Project.

The Xai-Xai Meteorological Station is located next to Xai-Xai town, north of the Limpopo Riwer Valley (Figure 40). Main ID-data are:

Station:	Xai-Xai
Altitude:	4 m
Latitude - longitude:	25º03'S; 33º38'E
Measuring height	10 m agl

20 years (1975 – 1994) of monthly average wind speed data are presented in Table 8 (in km/h) and in Figure 41 (in m/s). Wind data has not been collected on regularly basis since 1994. The data indicates large variation of the wind from year to year. The seasonal variation is very similar to that observed at Maputo Airport (Figure 22).

The maximum wind speeds observed at Xai-Xai Meteorological Station during the period 1975..1994 – indicated in Table 9 – is 124 km/h, corresponding to 34 m/s.

It is recommended to collect high quality wind data from the Jangamo site.

[2] Technical Assistance for Rural Electrification and Networks Reinforcement, EdM / CarlBro, 2004 (Danida).

Figure 40: Photos from the Xai-Xai Meteorological station towards east (upper) and south (lower). (Photo: CarlBro, 2004)

ESTAÇÃO: XAI - XAI

LATITUDE: 25º 03´S LONGITUDE: 33º 38´E ALTITUDE: 4 Metros

ELEMENTO: VELOCIDADE MÉDIA MENSAL DO VENTO (em Km/h)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1975	9.0	9.1	10.0	5.0	5.1	2.5	5.1	8.6	6.3	11.5	9.6	12.3
1976	9.3	6.0	5.1	7.3	6.4	4.5	3.7	9.9	9.2	11.8	10.6	6.1
1977	9.2	7.5	7.4	2.8	3.4	3.4	4.9	7.8	9.9	8.7	9.5	7.7
1978	8.4	6.8	2.8	6.0	4.8	6.7	3.5	5.7	9.1	11.6	10.1	10.6
1979	11.3	6.0	7.0	2.8	3.7	4.4	4.9	5.1	8.8	10.8	10.4	9.1
1980	9.4	4.6	5.0	5.4	5.9	4.4	3.2	4.8	8.8	7.6	5.7	4.4
1981	4.2	4.9	7.5	7.3	8.0	7.6	9.2	11.6	14.8	13.1	12.8	7.5
1982	11.3	10.3	8.3	5.1	4.6	4.9	6.0	7.1	7.5	9.3	8.7	9.2
1983	7.7	10.7	6.4	5.0	5.3	3.8	7.0	7.8	8.4	6.9	6.4	4.6
1984	7.1	9.0	4.9	4.1	4.3	3.3	3.4	3.0	4.2	4.8	5.5	6.8
1985	5.0	3.8	2.8	3.6	3.0	3.4	3.4	4.0	4.3	3.7	5.1	4.2
1986	3.5	3.0	4.2	2.5	1.9	2.3	2.1	3.2	4.7	4.8	5.2	4.2
1987	3.2	3.6	2.3	3.3	3.0	6.6	7.7	8.6	8.6	8.3	8.5	7.3
1988	10.5	8.9	6.6	6.5	6.0	7.5	5.0	7.4	10.7	12.3	12.4	8.1
1989	8.3	8.8	6.3	7.2	3.7	6.0	6.4	6.6	13.4	15.0	11.2	8.6
1990	8.8	8.1	7.0	5.5	4.9	--	5.8	--	10.6	--	11.6	5.7
1991	13.6	13.1	9.7	6.0	5.1	5.5	6.5	9.4	9.8	7.9	10.4	10.7
1992	11.2	8.6	10.8	8.0	6.1	8.3	10.1	--	14.3	13.8	14.3	14.3
1993	7.7	7.2	4.5	5.0	2.6	2.4	--	--	8.2	5.0	6.7	6.6
1994	4.0	3.7	4.1	3.8	2.8	6.4	7.5	6.9	--	--	--	10.0
1995	--	--	--	--	--	--	--	--	--	--	--	--
1996	--	--	--	--	--	--	--	--	--	--	--	--
1997	--	--	--	9.3	7.8	8.4	--	--	--	13.6	14.0	10.8
1998	9.5	--	7.1	--	--	--	--	11.3	13.3	--	--	--
1999	--	--	8.8	6.7	7.9	--	--	--	--	--	--	--
2000	--	--	--	--	--	--	--	--	--	--	--	--
2001	--	--	--	--	--	--	7.2	--	--	--	--	--
2002	--	--	--	--	--	--	--	--	--	--	--	--
2003	--	--	--	--	--	--	--	--	--	--	--	13.0

Table 8: Wind speed data (in km/h) from the Xai-Xai Meteorological Station. (Source: INAM, 2004)

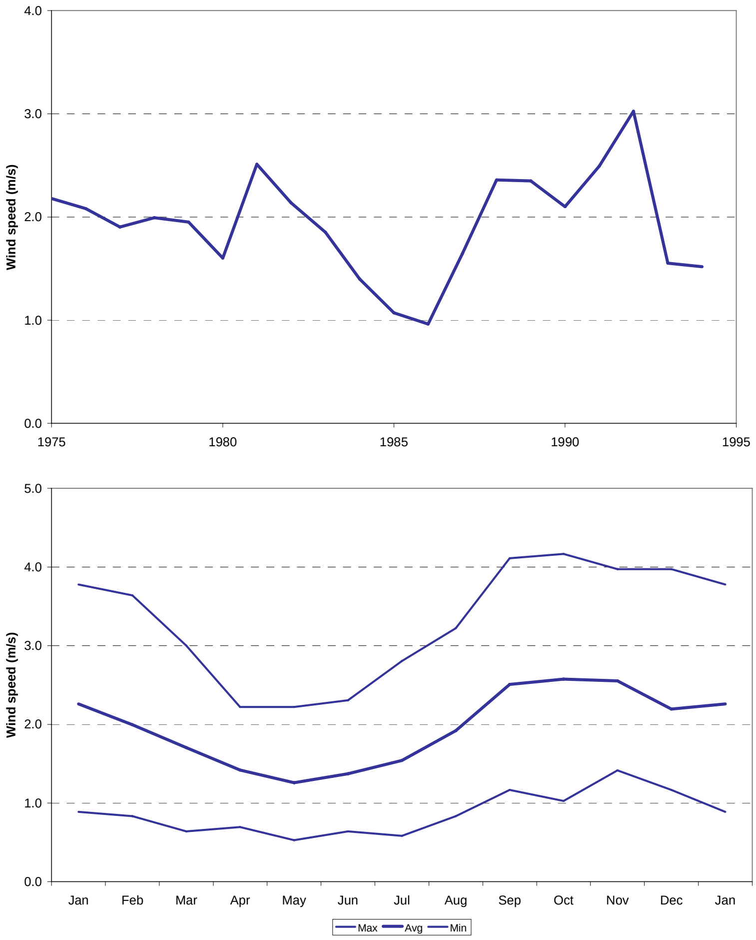

Figure 41: Plot of annual average wind speed (upper) and max / average / min monthly average wind speed (lower), both in m/s, observed at Xai-Xai Meteorological Station during the period 1975..1994 (data from Table 8).

ESTAÇÃO: XAI - XAI

LATITUDE: 25º 03´S LONGITUDE: 33º 38´E ALTITUDE: 4.0 Metros

ELEMENTO: RAJADA MAXIMA MENSAL (Km/h)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1975	S-60	SW-61	S-65	S-72	SE-68	SE-46	SW-54	SE-64	S-42	SW-84	SE-67	SW-77
1976	SE-70	SW-58	S-62	S-64	SW-54	SW-46	SW-64	SW-78	SW-84	S-84	S-64	S-45
1977	SW-60	SE-55	SE-64	SE-46	SE-58	N-66	SE-65	SE-58	SE-70	S-62	S-60	S-86
1978	SE-64	SE-60	N-34	SW-80	W-70	SW-76	S-54	S-57	SE-58	SE-71	SE-90	SE-80
1979	S-80	SE-43	S-76	S-78	SE-50	S-78	S-58	NW-52	S-66	SW-64	S-70	N-60
1980	S-62	SE-45	SE-50	SE-50	SE-56	SE-54	S-40	S-54	S-64	SE-56	W-56	SW-80
1981	NE-46	SE-44	S-56	S/SW-60	SW-68	SW-82	SW-66	S-68	S-82	SW-82	S-63	S-56
1982	S-56	S-60	SW-72	SE-40	S-46	S-51	SW-46	SW-59	S-35	S-50	SW-53	S-54
1983	S-40	S-46	S-48	S-45	SE-56	S-40	S/SW-42	SW-60	SE-42	S-54	S-76	SE-40
1984	SE-74	S/SW-46	SE-36	SE-38	S-50	S-40	S-38	SE-36	SE-38	SE-41	SW-36	S-46
1985	NE-40	SE-40	S-32	N-53	SW-38	SE-37	SW-50	S-33	S-40	SE-33	W-34	S-32
1986	S-28	SW-34	SW-39	SE-28	SW-32	SW-37	S/SE-30	S/SE-22	S-39	SE-36	S-38	SE-32
1987	S-30	E-28	E-22	S-22	S-22	--	--	SW-76	S-64	--	--	--
1988	--	--	--	--	--	SE-74	S-70	SE-63	S-68	SE-70	SE-82	S-72
1989	S-70	SE-56	SE-66	S-78	S-62	SW-61	NW-75	S-96	SE-68	SE-81	SW-77	S-64
1990	SE-84	SE-72	SW-94	SW-58	S-56	--	S-54	--	S-74	--	S-80	SE-54
1991	SE-83	SW-76	SE-64	SW-80	S-56	S-64	S-68	S-68	S/SW-68	SE-54	SW-88	S-84
1992	E-74	W-80	S-124	S-76	S-70	S-76	SW-84	--	S-71	SE-80	SE-106	E-86
1993	SE-77	SW-56	S-80	SE-60	SW-54	S-55	--	--	S-60	SE-48	S-62	S-72
1994	SW-56	S-64	SE-62	S-44	SE-100	N-68	W-74	S-76	--	--	--	S-76
1995	--	--	--	--	--	--	--	--	--	--	--	--
1996	--	--	--	--	--	--	--	--	--	--	--	--
1997	--	--	--	S-65	SW-56	N-48	--	--	--	S-78	W-62	S-56
1998	S-46	--	--	S-50	--	S-57	--	S-56	S-50	S-65	--	--
1999	--	--	SE-38	S-52	S-37	S-56	--	--	--	--	--	--
2000	--	--	--	--	--	--	--	--	--	--	--	--

Table 9: Maximum observed wind speed (in km/h) at the Xai-Xai Meteorological Station. (Source: INAM, 2004)

4 Technical feasibility

A technical feasibility analysis has been carried out for a proposed grid connected wind farm in the EdM South Region based on the information made available for the project.

Modern, cost efficient wind turbines designed for grid connection are commercial available within the rated capacity range 0.5-5 MW. For land based wind farms, the most economic size of the wind turbine units are within the range 1-2 MW. The relative cost of the wind turbine units (in $ per MW rated power capacity) decrease in general with increasing size. In general, the relative energy output (the annual GWh per m2 swept rotor area) increases with the hub height (and with the rated generator capacity). The relative cost of the civil work (for access roads, foundations etc) as well as of the electrical work also decrease with increased unit size due to the decreasing number of units needed for a given wind farm capacity. However, the logistics (unloading of equipment at harbour, transportation of the equipment over land, erection etc) becomes much more complicate and expensive with increased unit size and increased weight. Wind turbine unit size around 1 MW is recommended for the first project.

From experience, a wind power project less than 10 MW with uncertain perspectives for further business potential is of very little interest for the wind turbine suppliers, and the bids will become relative high – if any. On the other hand, we recommend getting experiences from a limited project. A 10-20 MW wind farm is recommended.

It was agreed to do the feasibility studies for a 10 MW wind farm south of Maputo, connected to the existing Salamanga power substation. The size of the wind turbine units should be around 1 MW.

During the final Mission within the Project, another potential wind farm site was

Figure 42: Open area along the road between the Ponta de Ouro site and the Salamanga Substation. (Photo: Riso, 2007)

identified and inspected – the Chicumbana site in the Limpopo River valley.

> The larger scale perspectives of wind power will be illustrated by a 100 MW wind farm north of Maputo, connected to the 110 kV power line between Maputo and Inhambane. No feasibility analysis will be made.

4.1 Salamanga wind farm

A 10 MW wind farm with 12 Gamesa G58 850 kW wind turbine units is used for the study.

A potential site has been identified on the map, but the site was unfortunately not visited during the Project. However, the site conditions are expected to be similar to

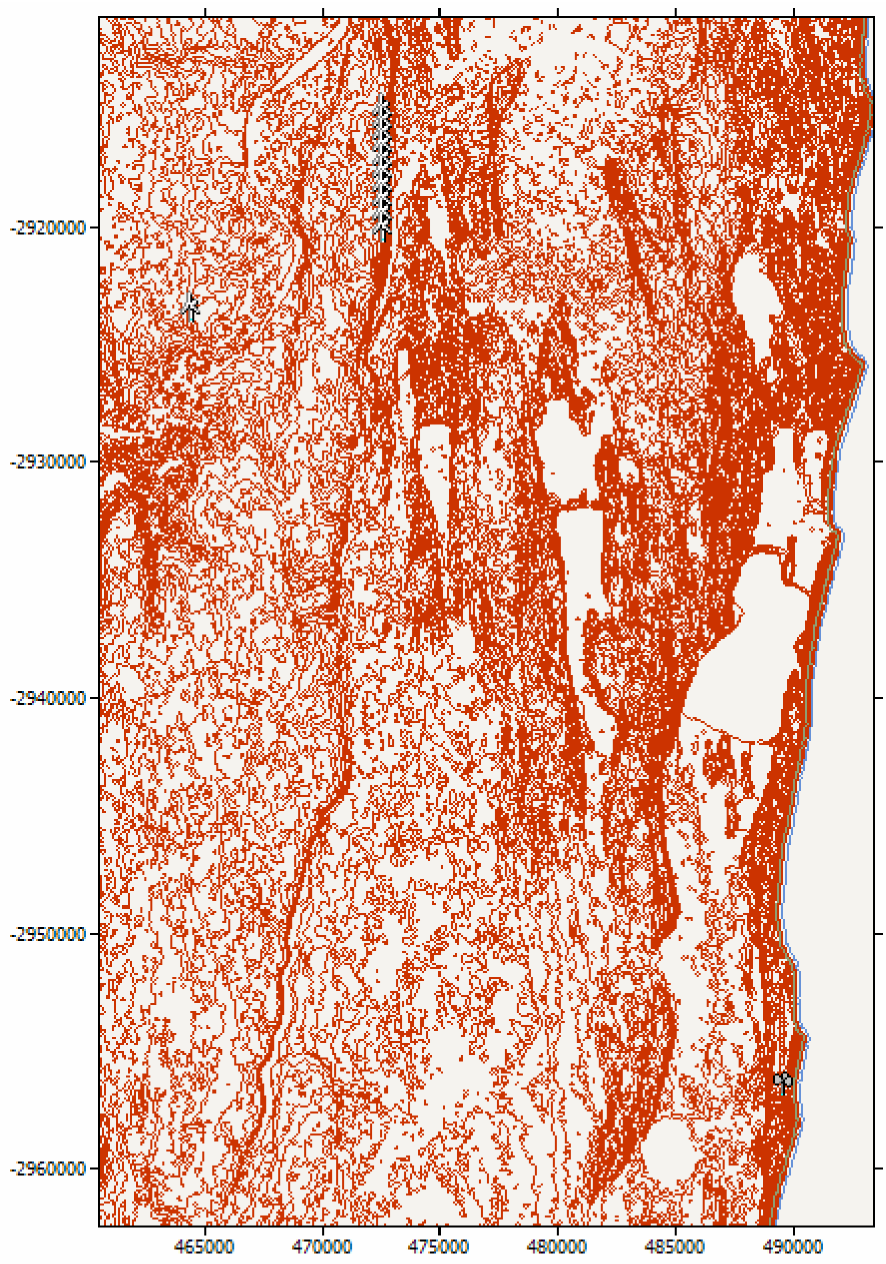

Figure 43: WAsP map of Ponta de Ouro site with 5 m height contour lines, with UTM coordinates (in meters) and with indication of the met-mast location, the Salamanga power sub station (indicated by a wind turbine symbol) and the Salamanga wind farm.

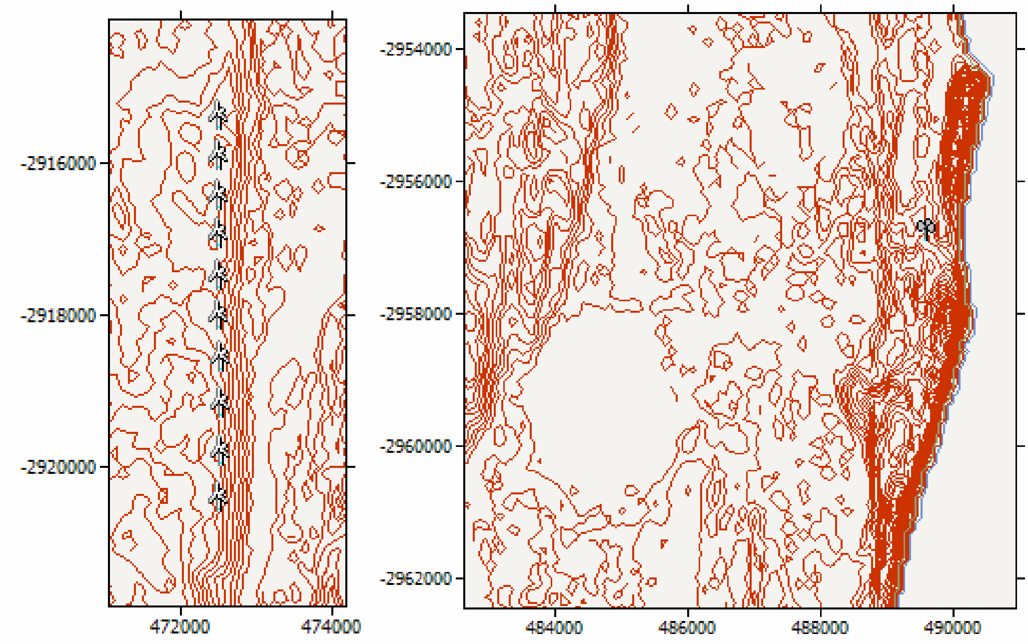

Figure 45: Details from Figure 43. Left: Salamanga wind farm. Right: Ponta de Ouro met-mast site.

those of Figure 42.

The study wind farm is located in a flat and open area 50 km south of Maputo, 30 km north of the Ponta de Ouro site, 20 km inland from the sea, and 10 km east of the Salamanga Substation. The wind farm is connected to the Salamanga Substation via a new 10 km long 33 kV overhead power line and a new 15 MVA / 66/33 kV transformer installed at the Salamanga power substation.

The Gamesa G58 850 kW wind turbine with 58 m rotor diameter and 44 m hub height has been applied as an example of a wind turbine with relative high rotor swept area relative to the rated power capacity (3.1 m^2/kW), resulting in relative high energy production from relative low wind, relevant for the wind conditions in Mozambique with moderate wind speeds. The power curve is illustrated in Figure 44 The wind turbine is designed for 50 m/s maximum wind speed, which is not expected to be a problem in the Maputo area.

Wind data has been measured and collected at Ponta do Ouro since March 2007 – see

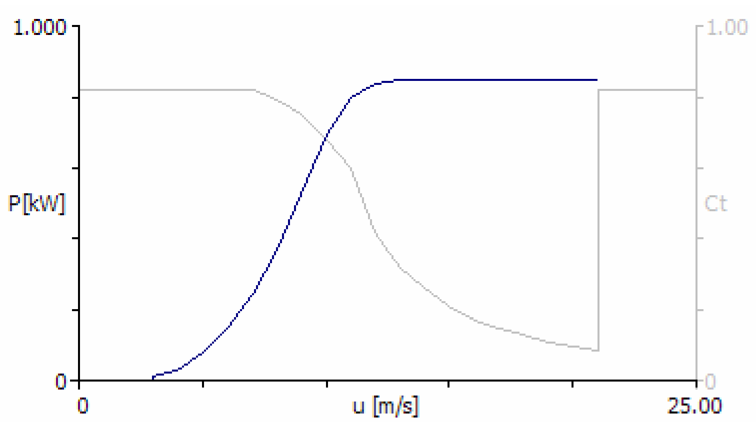

Figure 44: Power curve for the Gamesa 850 kW wind turbine with 58 m rotor diameter and 44 m hub height.

'Salamanga' Wind farm (18.609 GWh)

Settings | Statistics | Site list

Site ID	Site x [m]	Site y [m]	Elev. [m]	Ht [m]	U [m/s]	Gross [GWh]	Net. [GWh]	Loss [%]
Turbine site 4	472464.0	-2915515.0	42.0	44.0	6.05	1.936	1.903	1.71
Turbine site 5	472478.0	-2916047.0	41.0	44.0	5.99	1.889	1.818	3.75
Turbine site 6	472478.0	-2916564.0	45.0	44.0	6.09	1.970	1.890	4.07
Turbine site 7	472478.0	-2917068.0	45.0	44.0	6.13	2.004	1.924	4.02
Turbine site 8	472478.0	-2917641.0	40.0	44.0	6.01	1.905	1.830	3.94
Turbine site 9	472464.0	-2918159.0	37.0	44.0	5.94	1.850	1.773	4.14
Turbine site 10	472506.0	-2918704.0	40.0	44.0	6.00	1.905	1.833	3.77
Turbine site 11	472506.0	-2919305.0	43.0	44.0	6.04	1.931	1.865	3.41
Turbine site 12	472506.0	-2919935.0	43.0	44.0	5.99	1.894	1.836	3.05
Turbine site 13	472464.0	-2920550.0	47.0	44.0	6.09	1.976	1.938	1.91

Table 10: Annual power generation for the Salamanga wind farm estimated by WAsP and based on the wind data in Figure 28.

Figure 43 and Figure 28. A 40 m (??) communication mast is present at the Salamanga substation. The Consultant recommends establishing supplementing wind measurement equipment at the mast to verify the reduction in the wind energy inland relative to the coastline. The distance to the sea is 15 km and the distance to the Ponta de Ouro met-mast is 50 km. The wind data can be correlated to the data collected at Ponta de Ouro, and even few months of data will be valuable.

As indicated by the wind rose in Figure 31, unfortunately the wind flow at the Ponta de Ouro met-mast seems very much influenced by the north-south going dunes along the coast – see Figure 45.

The annual power generation for the Salamanga wind farm, estimated by WAsP and based on the wind data in Figure 28, is indicated in Table 10. The 18.6 GWh/y corresponds to a load factor of the wind turbines of 25 %.

4.2 Jangamo wind farm

An arbitrary 8.5 MW (10 units of 850 kW) wind farm has been

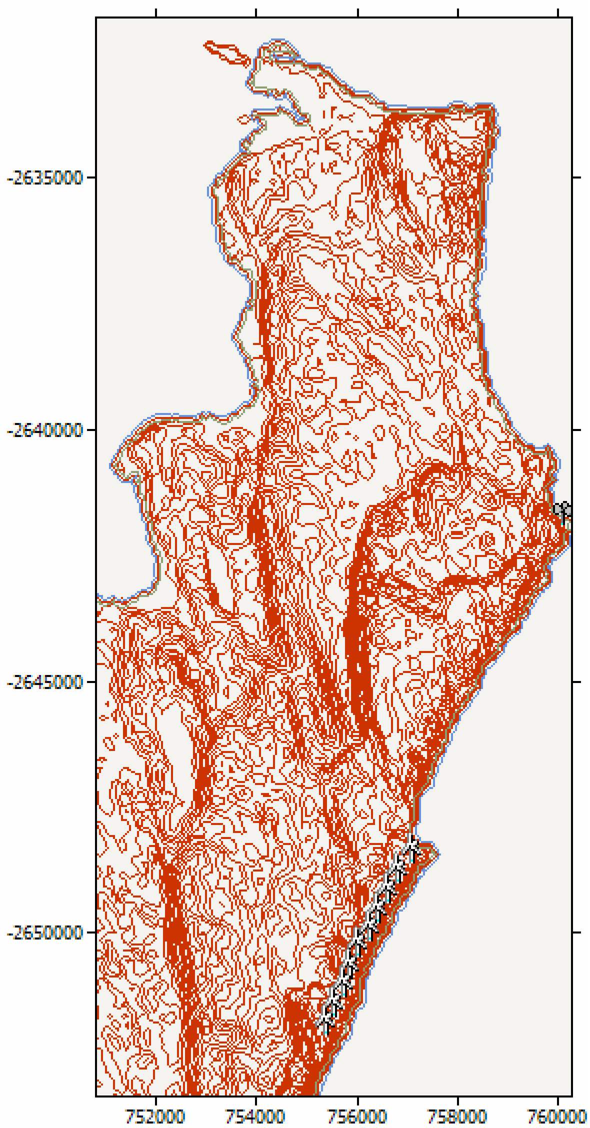

Figure 46: WAsP map of Tofo site with 5 m height contour lines, with UTM coordinates (in meters) and with indication of the met-mast location and the Jangamo wind farm.

'Jangamo' Wind farm (26.748 GWh)

Settings | Statistics | Site list

Site ID	Site x [m]	Site y [m]	Elev. [m]	Ht [m]	U [m/s]	Gross [GWh]	Net. [GWh]	Loss [%]
WT 01	757034.1	-2648565.0	41.0	44.0	7.18	2.846	2.831	0.54
WT 02	756764.2	-2648944.0	48.0	44.0	7.24	2.876	2.822	1.86
WT 03	756570.9	-2649369.0	45.0	44.0	7.17	2.814	2.754	2.13
WT 04	756375.2	-2649738.0	47.0	44.0	7.17	2.821	2.754	2.36
WT 05	756201.8	-2650099.0	45.0	44.0	7.13	2.786	2.715	2.52
WT 06	755986.8	-2650432.0	47.0	44.0	7.06	2.734	2.661	2.67
WT 07	755834.1	-2650855.0	40.0	44.0	6.74	2.499	2.434	2.61
WT 08	755681.5	-2651236.0	48.0	44.0	7.01	2.702	2.631	2.61
WT 09	755494.2	-2651625.0	42.0	44.0	6.76	2.518	2.454	2.57
WT 10	755362.4	-2651958.0	52.0	44.0	7.07	2.755	2.692	2.27

Table 11: Annual power generation for the Jangamo wind farm estimated by WAsP and based on the wind data in Figure 38.

applied at Jangamo, 10 km south of the Tofinho met-mast site.

Wind data has been measured and collected at Tofinho since March 2007 – see Figure 46 and Figure 35.

The annual power generation for the Jangamo wind farm, estimated by WAsP and based on the wind data in Figure 38, is indicated in Table 11. The 26.7 GWh/y corresponds to a load factor of the wind turbines of 36 %.

4.3 Chicumbane wind farm

The Chicumbane wind farm site is situated at the top-edge of a 50 m high NE-SW oriented slope towards the Limpopo River Valley, with the following UTM coordinates: N -2764251 m; E 555716 (Zone 36) – see Figure 47. The vegetation is low grasses and small dispersed bushes.

The estimated distribution of the wind resources, based on the measurements at Tofinho, and the location of the proposed wind farm with 10 wind turbine units are indicated at the WAsP map in Figure 48.

The annual production estimated by WAsP, based on the wind measurements at Tofinho is indicated in Table 12.

Figure 47: The slope at the proposed Chicumbane wind farm site seen from south from the Limpopo River Valley. (Photo: Riso, 2008)

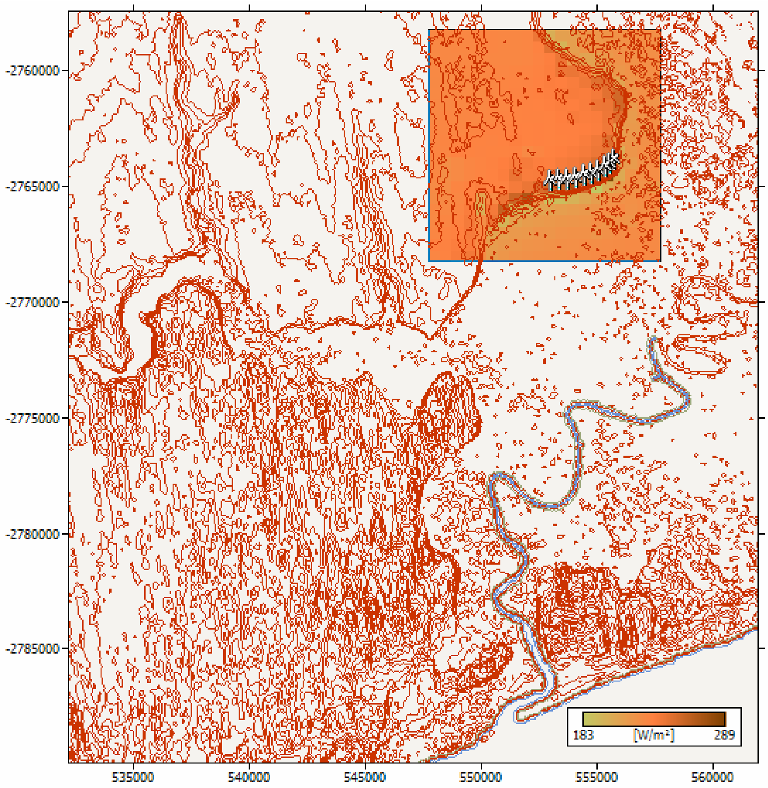

Figure 48: WAsP map of the Chicumbane site, indicating the proposed wind farm and the wind resources based on the measurements at Tofinho. (Source: Riso)

Figure 49

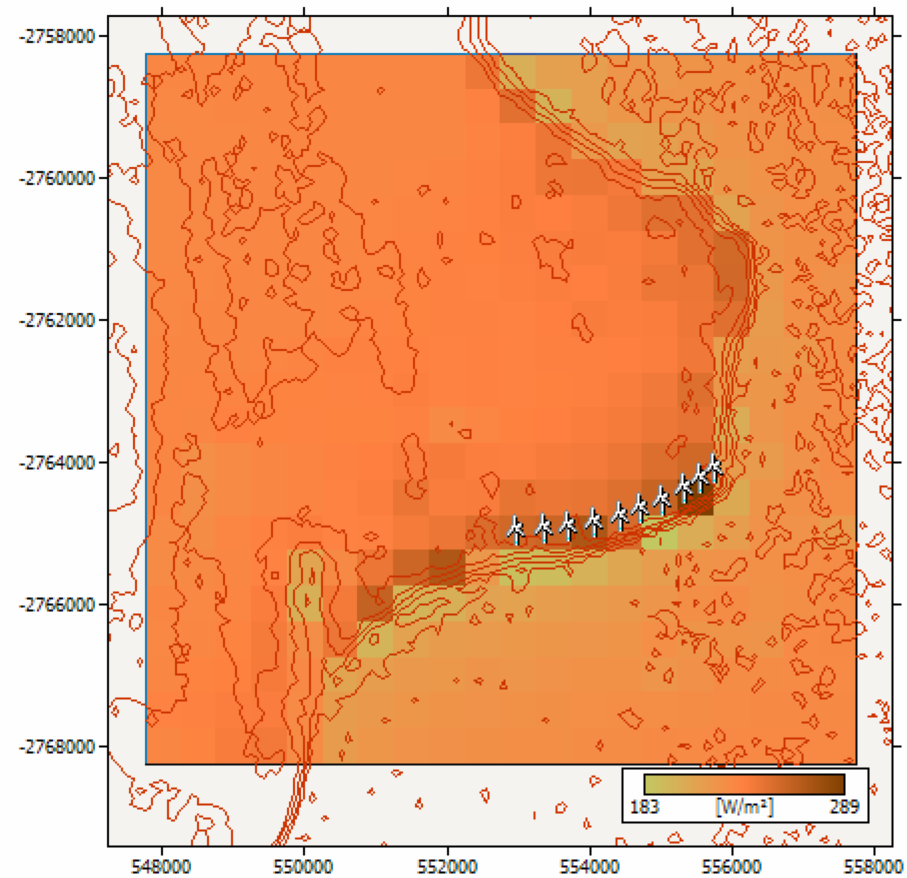

Figure 50: Detailes from the WAsP map of Figure 48.

'Chicumbane' Wind farm (18.326 GWh)

Settings | Statistics | Site list

Site ID	Site x [m]	Site y [m]	Elev. [m]	Ht [m]	U [m/s]	Gross [GWh]	Net. [GWh]	Loss [%]
Turbine site 1	552947.4	-2765128.0	40.0	44.0	6.22	1.815	1.791	1.33
Turbine site 2	553325.6	-2765094.0	40.0	44.0	6.21	1.810	1.781	1.62
Turbine site 3	553670.2	-2765060.0	40.0	44.0	6.22	1.817	1.787	1.65
Turbine site 4	554031.6	-2765001.0	40.0	44.0	6.25	1.839	1.810	1.56
Turbine site 5	554409.3	-2764913.0	40.0	44.0	6.31	1.885	1.849	1.89
Turbine site 6	554695.5	-2764817.0	40.0	44.0	6.31	1.879	1.842	2.01
Turbine site 7	555006.5	-2764699.0	40.0	44.0	6.31	1.880	1.840	2.1
Turbine site 8	555292.2	-2764539.0	42.0	44.0	6.29	1.861	1.812	2.6
Turbine site 9	555519.1	-2764396.0	44.0	44.0	6.31	1.879	1.823	2.99
Turbine site 10	555716.9	-2764251.0	50.0	44.0	6.52	2.015	1.990	1.25

Table 12: Chicumbane wind farm – results from WAsP analysis. (Source: Riso)

4.4 Power system analysis

Up to 100 MW of wind power can easily be integrated into the Maputo grid.

10 MW wind farms can easily be connected to both the Salamanga p and to the Xai-Xai power substations.

The estimated annual production for the three proposed wind farms – Jangamo (Inhambane), Chicumbana (Xai-Xai) and Salamanga – are compared in Table 13 with two wind turbine types – the Gamesa G52-850kW and the Gamesa G58-850kW. The highest production figures are indicated for the Jangamo wind farm. However, no suitable site have been identified in this area. The figures estimated for Chicumbana and Salamanga should be verified by local measurements.

The value of the generated wind power depends on how the wind power can contribute to fulfil the power demand in the power system and on the import / export power prices at the time of production. The wind power generation will have a typical daily profile and a typical seasonal profile.

In Figure 51 the variations of the wind power on hourly basis over the day registered at the Ponta de Ouro site are correlated to the variations of the power demand for the EdM South power system. In average, the variation of the wind power over the day correlates very well to the variation of the demand – raising the value of the wind power generation.

The only presently power generation capacity in EdM South region is the 16 MW Corumana hydro power plant, with limited water inflow and limited water reservoir capacity. The time series plot in Figure 52 of the monthly average values of the water level in the Corumana Dam and the wind power level at Maputo Airport indicates a tendency that the wind is high when the water level is low and vice versa – also raising the value of the wind power generation.

	10 x G52-850kW	10 x G58-850kW	
Jangamo	25.5	29.0	GWh/y
Chicumbana	18.5	21.5	GWh/y
Salamanga	14.5	17.5	GWh/y

Table 13: Comparison between estimated annual productions from the three proposed wind farms with two wind turbine types.

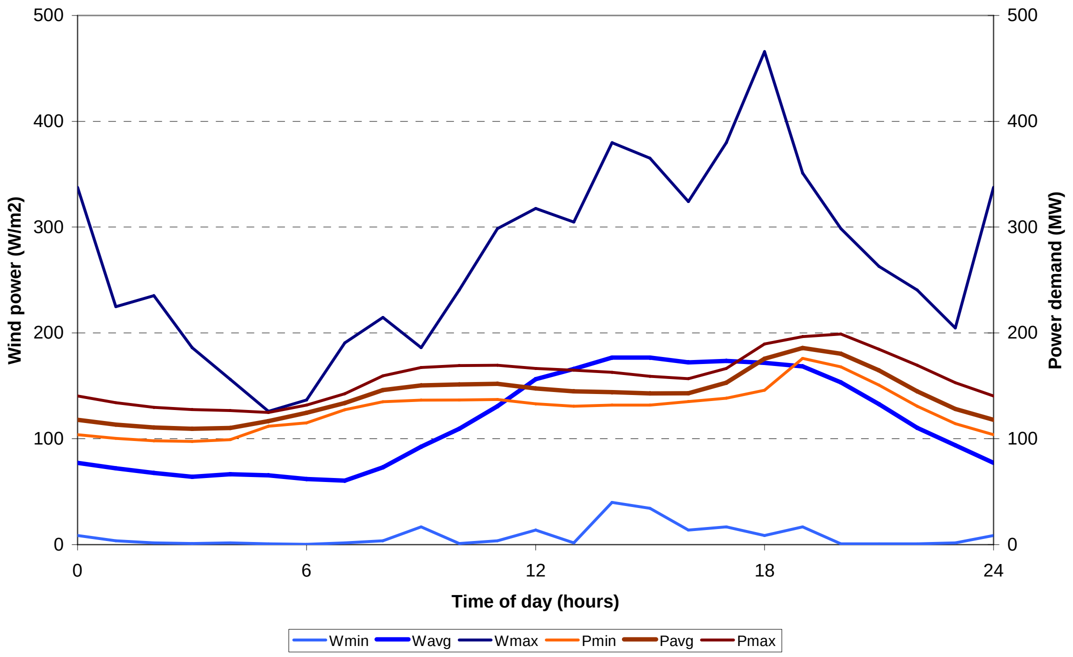

Figure 51: The correlation between the hourly wind power (in W/m^2; min values multiplied by 10; max values divided by 5) recorded at Ponta de Ouro at 29 m height level and the hourly EdM South power demand (in MW) in 2006.

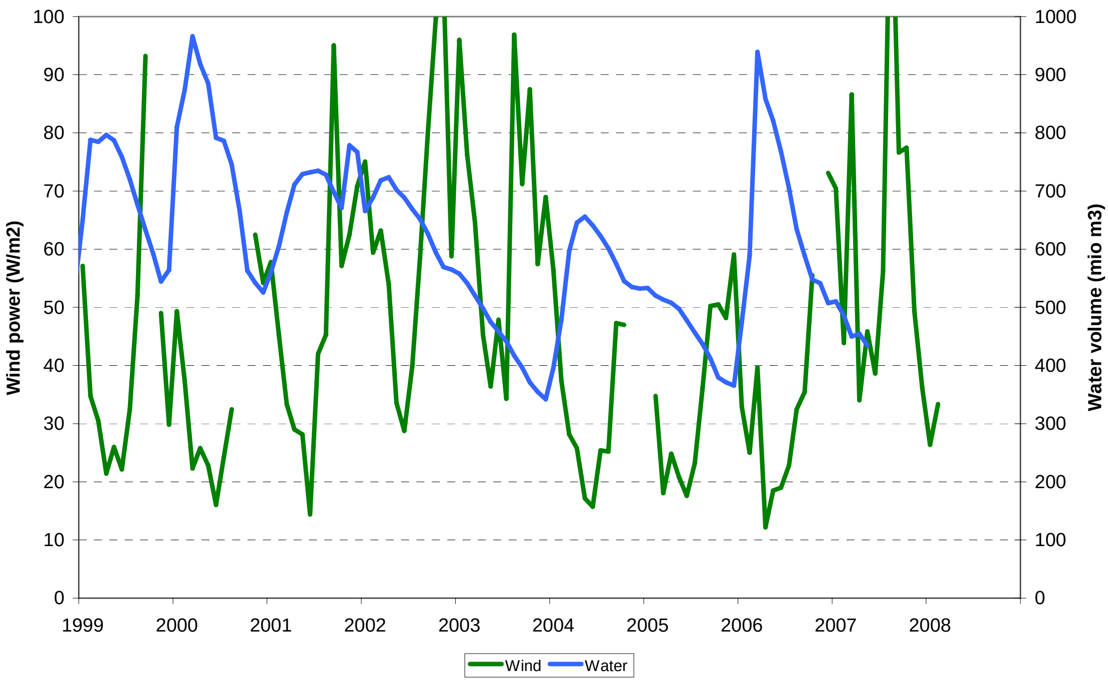

Figure 52: Correlation between the wind power measured at Matupo Airport and the water volume measured at the Corumana Dam.

5 Economic and financial evaluation

A preliminary evaluation of the proposed 10 MW Wind Energy Plant at Ponta de Ouro was carried out. According to the technical analysis, generation can be expected to be 18 GWh / year. Total investment costs are taken as US$20 million (transmission line costs have not been taken separately).

From the analysis, it is apparent that even with the current equipment prices and tariff based on EDM LRMC (9 cents as per report from African development fund), project viability is an issue. The project has very low IRR (about 4.3%; 5.3% with CDM), and a negative NPV at 12% discount rate. The project would qualify as a CDM project but carbon coefficient needs to be calculated. Considering current mix of electricity in Mozambique (mainly hydro), CDM may not be very attractive. But if projects in pipeline can be included (depending on how far they are from getting into the portfolio of projects), there may be some gains from the CDM. Since project viability is an issue, CDM benefits could become available even with concessional financing / grants by donors. CDM revenue may have marginal impact on IRR of the project, but it can have a significant impact on IRR for the investor.

The methodology and assumptions used for the financial analysis of this project are those normally used for project appraisal. The project was evaluated for its lifetime of 20 years. All costs and benefits data used in the analysis are based on current prices (2007 estimates).

Project financial feasibility was assessed by calculating net present value (NPV), and internal rate of return (IRR) of the project. Impacts of the expected CDM revenues (by selling CERs at $15 / ton) on NPV and IRR of the project were also calculated.

5.1 Data and Assumptions

Data used and assumptions made in the analysis are as follows:

Total Investment: Total investment was taken as US$20 million, which includes feasibility study, site and project development, plant and equipment, engineering and installation, and other miscellaneous expenses for the proposed 10 MW wind farm. This is based on US$ 2 million / MW costs for wind power plants; the costs are high since it has been a sellers market for quite some time. These are in 2007 costs and Investment is done in 2008, but no escalation is considered. Transmission costs have been taken as $250,000 (125000 for 5 kms 33 KV line, and 125000 for sub-station). Depreciation is taken as 5% per year and terminal value (salvage value) of 10% has been considered.

Annual Operation & Maintenance (O & M) Cost: It is taken as 2% of the investment in plant (excluding in transmission). This includes land lease, property taxes, personnel, insurance, spare parts, equipment repairs, travel, administrative costs, contingencies etc. O & M costs starts occurring only from 2009 (first year of plan operation), but no escalation in the prices is considered until first year of operation (2009). O & M costs are assumed to increase by 3% every year, over the previous year's costs after that.

Estimated annual energy output: As already discussed, 10 MW wind farm is expected to produce 18 GWh / year. It is assumed that this level of generation is achieved in the first year of the operation itself, and is maintained over the 20 year life of the plant.

Transmission losses to point of sale to distribution company are taken at 5%. Therefore power available for sale is 95% of the above generation.

Electricity sales price: Projected rate of power purchase by the distribution utility was taken as 9 US cents per unit (KWh) in 2007. It was taken to increase by 3% every year (over the previous year's price).

Financing Plan: The required investment is planned to be funded through 20% equity contribution, and the reminding 80% through loan (all domestic). An interest rate of 15% has been assumed for the loan, and a 15 year repayment period, with 6 year grace period. A spread of 3% on interest on loan was taken for hurdle rate (discount rate) calculations. A return of 12% on equity is required. An alternate financing plan was considered, with 0% interest rate and 15 year repayment period (with 6 year grace period – could be negotiated for wind energy from donors). No foreign exchange risk or guarantee was taken but a management fee of 1.5% was considered.

Revenues from the CDM: The combined margin emission factor was assumed at 0.6 t CO2 eq. / MWh for illustration purposes. The emission factor depends on mix of thermal and hydro in the system (current) and 5 most recent plants under construction. The factor used here is on higher side, considering the mix of hydro and thermal plants plans to be added to the grid between 2009 and 2015 (as per Ministry of Energy), and hence only for illustration. The purpose is to show impact of CDM on project viability, but will need to be properly calculated to find out the actual impact. Combined emission factor will need to be calculated from Simple Operating Margin Emission factor from current plants, and Build Margin Emission Factor from the recent plants under construction. CER prices can vary- $15 per ton has been considered for the base case. CDM revenue is expected to be available throughout plant life.

Other items: Tax on income was assumed nil. No taxes on equipment imports have been considered. Since transmission lines are a part of the investment, no separate access fee to the grid was considered.

5.2 What would make the wind power project viable?

(a) Project viability: Project IRR and NPV (at given discount rate of 12%) are primarily determined by capital cost of the project, maintenance costs, grid access costs and tax on income. Economic viability of the project (after taking out tax part) can therefore only get impacted if any of these parameters change.

- At a tariff of 16 cents / kWh, project has a marginally positive NPV at 12% discount rate, but the IRR is low at 12.7%. (13.5% with CDM). It reaches 15% (somewhat acceptable level) at a tariff of 18 cents/ kWh. But there may be no justification for these high tariffs, since these are way above LRMC of the EDM. Also, hurdle rate remains high due to high cost of capital, leading to negative NPV.
- If plant costs come down by 40% (since current market prices are very high with $2 mill / MW costs, as against 1 to 1.2 mill / MW for some plants in India and China, on which work was started 1-3 years back), IRR improves to 11,5% though NPV remains marginally negative.

(b) Project viability for Investor: Investor is primarily interested in financial returns, indicated by investor IRR and NPV at investor's hurdle rate. Investor's hurdle rate is basically cost of capital, which is a function of interest rate on loan, other financial

costs (guarantee, foreign exchange risk), return on equity needed, taxes and tax shield available, and spread required over the cost of capital. Concessional financing and / or grant can change the returns to investor and make the project viable for the investor.

- For example, at 0% interest rate (with a management fee of 1.5%), IRR for investor is 10.7 (15% with CDM). It reaches 16.2% (21.5% with CDM) if management fee is eliminated, but NPV at hurdle rate is still marginally negative.
- Similarly, a 50% grant increases investor IRR to 14.5% (18.9% with CDM), though NPV at hurdle rate is still negative.
- A 25% grant with 0% interest rate gives very attractive result; NPV turns positive and is high; investor IRR shoots up to 30.4%.

A combination of grant, concessional finance, CDM revenues, and tariff can thus impact the IRR and make the project financially viable.

5.3 Should the wind energy considered as an option in Mozambique?

Current economic evaluation may not favour development of wind energy in Mozambique, and yet there are several other factors that should be considered in a decision making on this issue. The tariff considered in this case is 9 cents / kWh. Since EDM imports energy from South Africa, if there is a possibility of imports in future at prices higher than this, the higher price becomes relevant for the evaluation. On the other hand, several new power projects are in pipe line and power from these may be exported. In this case also, if cost of production from any of these plants is higher than 0.9 cents/ kWh, or export price of power is higher than this, the higher figure should be considered in the evaluation. Higher value will improve economic viability indicated by this analysis.

It is difficult to predict future electricity prices in the SAPP but if current situation is any guide, prices can be expected to harden in short and medium term[3]. This is due to shortages in South Africa, the biggest player in SAPP, which are expected to aggravate in near future despite their plans to augment supply. Current capacity addition plans in the SAPP reason are inadequate to meet the rising demand from South Africa[4].

Wind energy is an environmentally friendly energy and increasing pressure to shift from dirty fuels may put more emphasis on development of wind energy or other renewable energy in future. Also, prices of wind turbines can be expected to come down substantially (40% or more), once the temporary supply shortages gets eliminated and market becomes competitive again. Some of the Indian and Chinese wind energy plants currently under construction have prices more than 40% below current world market prices. The two factors (pressure due to environmental issues and expected decrease in capital costs) may favour continuation of activities in this area, although on a small scale, so that skill is developed to take advantage of the future opportunities.

In case of many countries, wind energy development has been spurred by energy security considerations. This does not seem to be much relevant in Mozambique, since several resources to meet energy requirement are available within the country.

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[3] Current prices see at the Southern African Power Pool at http://www.sapp.co.zw/

[4] Based on discussions with Anders C. Pedersen, Economist EDM.

Also, although there are several regions without access to electricity in the areas where wind energy can be developed, wind energy alone can not be a solution to this. Due to nature of wind resource (which may not blow when electricity is needed), the power generated by wind plants needs to be fed to grid, which can then make necessary changes in the system to absorb the wind power. Hybrid systems are now being discussed to address this issue but it make some time before hybrid systems can be optimized for these applications.

6 Institutional and economic feasibility study[5]

6.1 Present relevant institutional framework

6.1.1 Energy policies and other relevant strategies

Non commercial energy, primarily coming from forest resources, provides 85% of the overall energy needs of the Mozambique. The Cahora Bassa hydro power station with 2075 MW capacity is the only big power station and bulk of power produced (more than 80%) is exported to South Africa. Hydro potential is substantial, originally estimated to be 12000-14000 MW, most of it in the Zambezi valley. Of this, about 2352 MW has been so far exploited. Several small hydro plants are operated by the EDM, but only two, Chicamba and Mavuzi, have significant capacity.

Besides the hydropower resources, Mozambique has significant reserves of natural gas at Pande, Temane and Buzi. Pande (240kVA) and Temane (1890kW) gas are used for local generation of electricity in Nova Mambone, Vilankulo and Inhassoro. The gas fields of Temane are primarily producing gas for export to South Africa and there are plans for using the gas in Mozambique including steel production. Mozambique also has three relatively large known deposits of coal at Moatize-Minjova, Senangoe and Mucanha-Vuzi, all of them in the province of Tete. Total coal reserves are estimated at about three billion tonnes. The 2 bn tonne Moatize coal mine is being developed by the Brazilian company CVRD to produce 14 m tonnes of coal per year. Most of this is for exports but CVRD is seeking a partner to build a thermal power station at the mine.

Mozambique has low population density with a vast geographical area. This makes distribution of commercial energy expensive. Only about 8% of the population has currently access to electricity. Mozambique thus needs to develop its energy sources to provide commercial energy to the rest of the population. The Government intend to increase to 54.1% by the year of 2009[6], which implies a 10.80% increase per annum in order to meet the target. Mozambique faces challenges in the form of a lack of access to finance, shortage of skilled human resources, and faces the constraints of limited paying capacity of the people to meet the target.

There is a huge regional demand for Mozambican power, particularly from South Africa. Therefore, there is shortage of power for local industry development; several major industrial projects (e.g. MOZAL III) are held up for this reason. About 2,352 MW power is generated in Mozambique, of which 365 MW (net) is exported, and Mozal uses 850 MW. The Ministry of Energy has planned several new plants. This includes development of further projects on the Zambezi; a 1500MW at Mphanda Nkuwa (and some extras may come up at Cahora Bassa; 550 MW had been mentioned at one time) has been planned. A 120 MW hydro plant at Lúrio and a 25

[5] Ministry of Energy, particularly Mr. Chicachama provided the inputs and also reviewed this chapter on institutional framework. Mr De Lima at Dept. of Alternate Energy also provided inputs for this chapter, as well for other chapters.
[6] http://www.dfid.gov.uk/countries/africa/Mozambique/Energy.pdf

MW at Massingir have also been planned. In addition to this two thermal stations are also planned; a 450 MW gas based at Chókwè in Inhambane Gaza, and a 1500 MW coal based at Moatize.

The EDM has a total installed capacity of 316 MW. The installed hydro capacity of EDM is around 110 MW, but dependable capacity is around 95 MW only. Some diesel power plants, dispersed in remote rural areas, constitute the thermal capacity of the EDM. In addition, EDM has entitlement to 300 MW from Cohar Bassa, all of which is used during the peak. EDM had 2357 GWh of electric power available in 2006, of which 360 GWh was exported. Balance was sold at an average selling price of 8.75 UScents/kWh, after taking out EDMs own consumption and transmission and distribution losses (about 19% in 2006). The peak load in the EDM system is currently on the order of 270 MW, still well below the total capacity available from Cahora Bassa and other smaller hydro schemes.

The company has also committed itself to investment $382.1 million between 2000-2009, of which 70 per cent is to be financed externally. Financing agreements for new projects were negotiated in 2006 for a total of $137 million.

The Energy Policy: The energy policy, formulated in 1997[7], has the following objectives:

- To ensure reliable energy supply, at the lowest possible cost, so as to satisfy current levels of consumption, and the needs of economic development;
- To increase the availability of energy for the domestic sector, particularly coal, kerosene, gas and electricity;
- To promote reforestation in order to increase the availability of firewood and charcoal;
- To strengthen the institutional capacity of the main agencies that supply energy, in order to improve their performance;
- To promote economically viable investment programmes, with a view to the development of energy resources (hydro-electricity, forests, coal and natural gas);
- To increase the exports of energy products;
- To increase efficiency in the use of energy;
- To promote the development of conversion technologies and environmentally benign energy uses (solar power, wind power and biomass);
- To promote a more efficient, dynamic and competitive business sector.

The IPP participation has been considered through the adoption of a single buyer model, with competition as the model for reform. Restructuring of EDM through vertical separation into hydro generation, transmission (including power procurement) and distribution business, complemented by horizontal separation of distribution through concessions (to EDM municipalities and private participants) for well-defined geographical areas is also on the agenda. Other initiatives under active consideration include strengthening of private sector participation by:

i. introducing independent power producers (IPPs) in new generation projects, and possibly selling the existing hydro business;

[7] Scanteam, 2005. Alignment, Harmonisation and Coordination in the Energy Sector, Mozambique, Oslo.

ii. letting management contracts for distribution business followed by leases / concessions contracts; and

iii. outsourcing non-core transmission and distribution functions.

iv. establishment of a mechanism and institutional arrangement for tariff regulation;

v. independent regulatory agency established by primary legislation; and

vi. consideration of a multi-sectoral regulatory agency (at least for electricity and gas) as longer term goal.

Other Energy Related Legislative Framework: The other related legislative frameworks and regulations include the following:

The Electricity Law (No. 21/97): The new Electricity Act approved in 1997 defines the general policy for the organisation of the electrical energy sector and the administration of the supply of electrical energy. It also defines the general legal framework for electrical energy generation, transmission, distribution and sale within the country, as well as its exportation to and importation from outside of the national territory, and granting concessions for such activities.

Municipal Legislation: A new municipal legislation was also enacted in 1997, which allocates some functions in investment planning and the operation of electricity services to local authorities.

The Energy Strategy (2000): The Energy Strategy complements the Energy Policy, indicating the plan of action for the energy sector. The strategy also considers the following:

- Limited access to finance
- Development of large scale projects and exports;
- Development of institutional capacity and efficiency
- Regulatory issues and,
- Issues related to environment, health and safety.

The government is considering IPPs to address the problem of access to finance for augmenting the generation capacity. Restructuring of EDM, establishment of a regulatory authority and a mechanism for tariff regulation are also under consideration.

PARPA and the Performance Assessment Framework (PAF): Mozambique's Poverty Reduction Strategy, PARPA, includes energy as one of the six main issues. The Performance Assessment Framework for the PARPA is to monitor the performance of the Government's efforts to reduce the country's poverty. It contains annual and tri-annual targets in the areas that are included in the PARPA. The first PARPA review exercise was carried out in April 2004. During this exercise, it was clear that for the energy sector, the goals remained vague, and the poverty-impact analysis incomplete. One of the energy policy objectives is to increase of availability of energy for the households, but requires clarity and target setting in terms of mix of energy, considering the capacity and willingness of poor households to pay for the energy. A lack of access to modern energy itself is a constraint for households to increase their income. This issue needs to be addressed by the strategy.

Concession Approach for Private Participation in Electricity Supply: Private participation in electricity supply, using concession approach was implemented in

1999 in Vilankulos and two adjacent towns, and the experience was used to refine the approach. The constraints such as capacity limitations and high tariffs did not allow the access to additional customers. Subsidy levels of 50% have been used to make the project economically viable, and tariff charged is twice the national tariff (EDM charges uniform national tariff from households). The access therefore has been an issue. A new concessionaire was successfully awarded the concession, discussed in a later section. The tariff in that case also a major issue.

6.1.2 Governmental and other organisations with linkages to power sector

Restructuring of energy sector is an ongoing process in Mozambique as a part of the overall restructuring of the country's economy and World Bank and GEF supported power sector reform project, leading to emphasis on market based solutions. Large scale power sector projects planned for near future with private sector participation, close integration with regional grid to export extra power, and promising opportunities on biofuel (biodiesel) front, all are further catalyst to drive changes.

The Ministry of Energy was carved out of the Ministry of Mineral Resources and Energy by the Presidential Decree No.13/2005 of 04 February.

According to that decree, Ministry of Energy (ME) is a central organ of the state apparatus which take the lead, plans, promotes and controls the inventory and use of energy resources, and the development and expansion of the supplying and distributing network of power, natural gas and oil products.

According to the article 2 of presidential decree no. 21/2005 of 31st March, the following attributes are for the ME:

a) promotion of a bigger knowledge of the energy resources of the country;

b) promotion of development and better use of the energetic potentials of the country;

c) promotion of the increasing the access to modern energy sources especially in the rural areas;

d) production an efficient use of energy particularly in the rural areas, in view to stimulate socio-economic growing and development;

e) promote and encourage private participation in the development of energy infrastructures;

f) Guaranty of sustainable development, equitable and secure of storing, distributing, supplying infrastructures and commercialization of natural gas and oil products.

g) Mitigation of environmental impacts of consumption and supplying of energy;

h) Guaranty of rational mechanisms in the formulation and application of oil prices and its derivates;

i) Energetic production for the satisfaction of the country's energy needs and for the opportunities in the regional market;

j) Distribution of oil products nationwide, particularly in the rural areas.

The organisational chart of the Ministry of Energy can be seen in the Figure 53. The directorates responsible for various types of energy sources, and planning include Directorate of Electrical Energy (DNEE), Directorate of New and Renewable

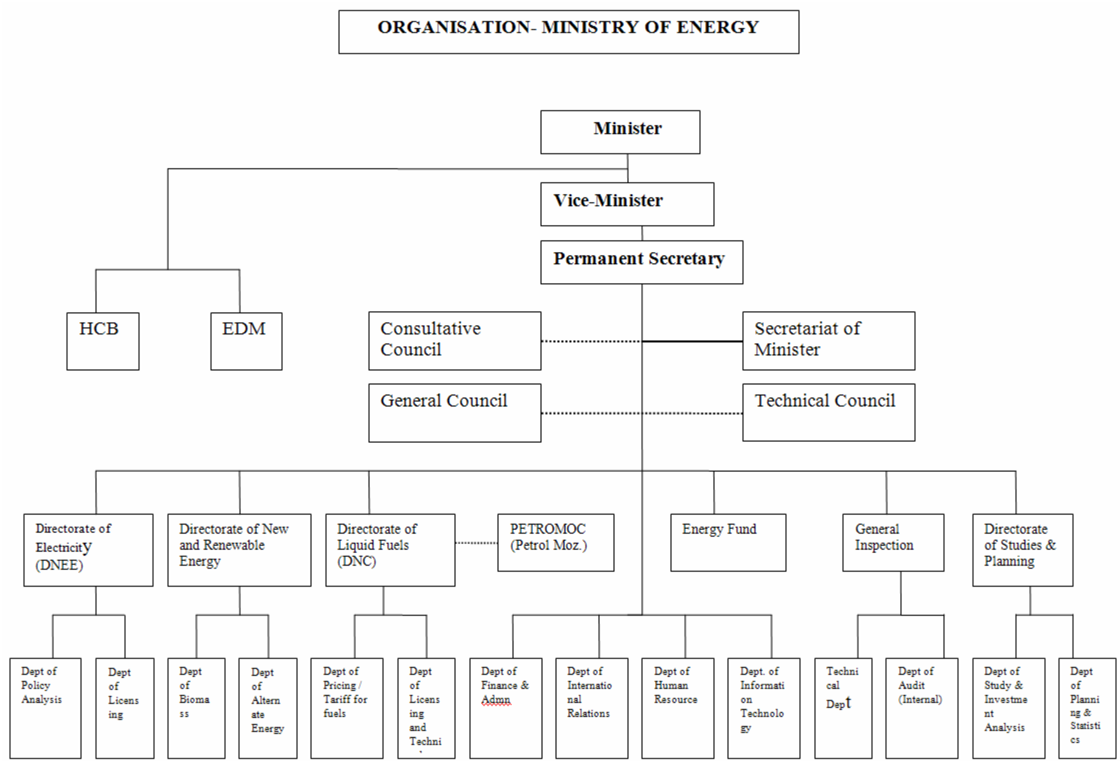

Figure 53: Source: Ministry of Energy, Mozambique.

Energies (DNER), Directorate of Liquid Fuels (DNC), and Directorate of Planning and Studies (DEP).

Other important entities are the National Electricity Council (Conselho Nacional de Electricidade, CNELEC), the corporatised but state-owned electric utility (Electricidade de Moçambique, EDM), the state-owned national hydrocarbon enterprise ENH which is engaged in upstream gas development. The National Energy Fund (Fundo Nacional de Energia, FUNAE) has been set up to fund new energy projects. The technical unit for hydropower implementation, UTIP (Unidade Técnica de Implementação dos Projetos Hidroeléctricos), is responsible for large-scale hydropower development.

National Electricity Council (CNELEC): CNELEC was established on the basis of the Electricity Act of 1997 and in principle is to become a regulatory body. Today it has an advisory and arbitration role that is not very clear, but it also remains organizationally weak with few staff in place. More important is that the power sector still has a structure where the regulatory function really is not required yet. There is a serious question whether the establishment of CNELEC is premature, and that its establishment may fragment the very limited resources the public sector has for managing the energy sector.

Technical Unit for Hydroelectric Projects (UTIP): UTIP was established largely to develop and promote large-scale power projects along the Zambezi River. The main activity so far has been the design and appraisal of the large Mepande Uncua power project below the Cahora Bassa dam. UTIP is now suggested as a more general development and promoting entity for power projects in Mozambique, also looking into the north bank potential at Cahora Bassa and possibly other medium-scale power projects. This proposal is currently being looked into by the political authorities.

Electricidade de Moçambique (EDM): EDM is the national utility of Mozambique. It used to be a state entity, but in 1977 was converted into a government-owned public company. It is largely a transmission and distribution utility, where its peak load recently reached 270 MW. This is small when compared with Cahora Bassa's generation capacity of 2,075 MW, and MOTRACO's transmission capacity of 850 MW. EDM is undergoing a restructuring process through the separation of accounts and the creation of business units. As a result EDM operates under a three-year performance contract with the GOM.

EDM has prepared a Master Plan for the expansion of the country's national power grid and distribution networks with the goal of reaching 15-20% of the population by the year 2020. EDM applies cross-subsidisation on a large scale, but it is transparent due to three business units. This process is automatic by applying a uniform tariff structure throughout the country.

Fundo de Energia (FUNAE): FUNAE has been established as an independent fund by decree in 1997. It is to raise and administer funds to support public and private energy production and distribution. The vision of FUNAE is to provide access to economic and sustainable energy solutions for a major part of the rural population, and manage the natural resources which contribute to the national development. The objectives of FUNAE are:

- Provide funding for financing sustainable energy projects in rural areas;
- Manage funds for on-lending;
- Promote opportunities for the private sector;
- Promote the use of renewable energy.

FUNAE uses a number of financing mechanisms to attain these objectives: loans with a maximum repayment period of 10 years; grants; and mixed financing and subsidy, depending on the project type and its viability. Private sector competition will be fostered through public tendering.

Ministry of Agriculture and Rural Development (MADER): The management of traditional fuels that are forest-based is under the Ministry of Agriculture and Rural Development (Ministério da Agricultura e Desenvolvimento Rural, MADER). The National Directorate of Forestry and Wildlife (Direcção Nacional de Florestas e Fauna Bravía, DNFFB) carries the responsibility for ensuring the sustainability of supply through its provincial offices (Serviço Provincial de Florestas e Fauna Bravía, SPFFB). A system of licensing exists for charcoal production and sale, but it does not appear to function well. Over-exploitation is common near urban centres, while much of the resources are under-utilised due to lack of access.

Now the Ministry of Agriculture and Rural Development has undergone changes. Ministry of Agriculture is a separate entity now.

Ministry for the Coordination of Environmental Affairs, MICOA: MICOA, (Ministério para a Coordenação a Acção Impacto Ambiental,) has legislative power regarding the environment, and one of its key functions is to coordinate with line ministries on such matters. Strong links to both MADER and MIREME are thus required, as MICOA is responsible for Environmental Impact Assessment approvals, but also Kyoto Protocol reporting and for any future Clean Development Mechanism application, all of which are relevant to the energy sector.

6.1.3 Private Sector Organisations

Hidroeléctrica de Cahora Bassa (HCB): HCB is privately owned by Portugal and Mozambique. Cahora Bassa is the largest single power plant in the Southern Africa region. Most of the power generated by HCB is exported to South Africa, a part of which is re-imported in the Southern part of Mozambique for Mozal. Due to tariffs in favour of South Africa, HCB has been running into losses and required restructuring. Actually Mozambique is in charge of the management of the Dam after paying the remaining amount to the Portuguese owning 85% of the shares and the remaining 15 with the Portuguese, since November 2007. The outcome of negotiations will be of interest to private investors to invest in new large-scale power generation in Mozambique – particularly in Mepande Uncua and the north bank of Cahora Bassa.

Mozambique Transmission Company (MOTRACO): MOTRACO has been formed jointly by ESKOM, South Africa's electric utility, EDM and the Swaziland Electricity Board, to supply electricity from South Africa to Swaziland and Maputo. In Mozambique, power supply is primarily for the Mozal aluminium smelter, and some of this is also being provided to the southern grid.

Southern Africa Power Pool (SAPP): SAPP was created in 1995 and aims at creating one single interconnected grid in Southern Africa. Mozambique is a member with the second largest generating capacity after South Africa, and the SAPP is important in a regional context. There are 12 members in the pool, all of which are national utilities, where nine of these are interconnected. ESKOM accounts for more than 82% of generating capacity in SAPP and over 85% of peak demand. This monopoly purchasing power has facilitated ESKOM buy Cahora Bassa power at very low rates. ESKOM's power is a key factor when assessing possible alternative structures for the power market in Mozambique.

6.1.4 Other Relevant Activities

Mozambique Energy Reform and Access Program (ERAP): This is a World Bank / GEF project, initiated in 2003, with a total cost of 81.5 million dollars. The program will increase access to modern energy in peri-urban and rural areas, thereby facilitating improved quality of life of the respective communities and generating income. It comprises: (i) reforms necessary for improved performance of the energy sector (in particular electricity) and accelerated access to electricity, in rural and peri-urban communities, and (ii) investments in electricity supply infrastructure (including renewables).

However with respect to ERAP, implementation is significantly behind schedule and this is reflected in the very low disbursements. This is in part due to a rethinking of the approach to sector reform which has culminated in the Ministry of Energy's new approach communicated to the donors in November 2005. Because of low institutional capacity, according to the Government, the privatization is not a feasible option and that the thrust of the sector reforms will be to improve the performance and efficiency of the utility- EDM. As such, donors generally share this view. Reforms are now being re-focused on enhancing the commercial viability of EDM through an improved performance monitoring framework called Performance Contract to be signed between EDM and the Government. However, restructuring studies will be carried out aimed at unbundling the EDM into separate business units along functional lines and creating an independent transmission company as well as introducing private equity participation in the EDM.

Fortis wind/ water pumping system: In August 2005 Fortis installed a complete wind / water pumping system in Mozambique. The system consist of 2 Fortis Montana 5 kW wind turbines, with 18 m guyed tower, controllers, fusebox, battery bank of 400 Ah/120V, 20 kVA sinewave 3 phase inverter and complete pump system with 2 submersible pumps of 3,5 kVA and suitable to pump 10 m3/hour from 100 m well. Fortis supplied the system as a complete turnkey system. The system will also be used for lighting and tools in the farm house and the workshop. The Fortis system is first wind turbine producing power (to pump water) in Mozambique.

Concession Approach in Mozambique: Mozambique's privately operated concession to generate, distribute, and sell electricity is up and running in a rural area of Inhambane Province isolated from the country's main transmission grid. The winning consortium of ElectroTec (Mozambique) and Rural Maintenance and Siemens (South Africa) bid an average tariff of 18¢ per kWh. Although this tariff is higher than the previous tariffs (much higher than the EDM tariff of 7¢ per kWh), community members agreed that they were willing to accept higher charges in return for much better service. The household dependent on diesel generated power pay similar or more rates. The contract was won through competitive bidding and leaves the private operator free to develop the power system in the concession area in the way most cost-effective. Subsidies have been provided to keep cost low. The subsidies are output based contingent on physical verification of households being connected. The concession however has since been revoked.

Donor Interventions: There are broadly two categories of funding agencies; Lending Institutions providing credits (loans): African Development Bank (AfDB), Arab Development Bank for Africa (BADEA), Islamic Development Bank (IDB), Nordic Development Fund (NDF), Agence Française pour le Développement (AFD, France), Kreditanstalt für Wiederaufbau (KfW, Germany), OPEC Fund, Kuwait Fund, World Bank (WB). Loan funding is concessionary, and commonly for infrastructure investments. Grants Donors include Danida (Denmark), NORAD (Norway), and Sida (Sweden). Spain and Japan have also provided some grants.

The major objective of interventions has been to expand the national electricity grid beyond urban towns and to assist in reforms to the energy sector.

DANIDA is funding EdM Southern Region Control Center, rural electrification and system improvement in Maputo, as well as providing institutional support to the Ministry of Energy in terms of advisers and training of officials. The Danish Government also supports the program for dissemination of solar systems and cooking stoves to conserve biomass in Sofala province. Norway is extending support for transmission line development and rural electrification. Swedish International Development Agency is expected to fund the rehabilitation of hydropower plants and provide institutional support to the Ministry of Energy. AFD has supported Mozambique-Zimbabwe interconnection, EdM billing system and a loan for development of Pande and Temane gas fields. Islamic Development Bank is funding the electrification of Cabo Delgado. Towards helping Mozambique utilize renewable energy sources, Spain is providing assistance for expansion of Solar PV. United Nations Industrial Development Organization (UNIDO) is setting up three pilot community Development Centres (CDC) in Kazula, Rotanda, and Sembezeia in central region in Mozambique. The CDCs will be powered by renewable energy hybrid systems. The objective is also to build local capacities at the CDCs to operate, maintain and also fabricate these units in the rural context. The project will provide

decentralized power to run the community centres with common facilities, namely to local enterprises, schools, training centres and health centres, leading to a range of social and economic benefits that will help alleviate poverty and improve the standard of living along with other benefits. Upon completion and successful operation; the pilots can be replicated in other villages in the regions.

6.2 Independent Power Producer (IPP) and owner ship issues

The Mozambique government has decided that the buyer of the wind produced electricity will be EDM but the ownership of the wind projects can rest with IPPs.

6.2.1 IPP Models

An electricity system can operate on four different models. These are:

(i) Natural Monopoly: In this, utilities are vertically integrated with no competition in generation, transmission and distribution. No one has choice of supplier in this case. The system tends to be opaque and inefficient in this case.

(ii) Single Buyer: In this case there is only one buyer (one distribution company), who chooses from various generators (IIPs). IPPs generate the electricity and make it available to the buyer. There is some competition in this case, but only in generation.

Mozambique government has decided to follow this model.

(iii) Wholesale Competition: In this case, there are several distribution companies and they buy directly from the IPPs. However, customers of distribution companies have no option but to buy from single supplier (their distribution company). The IPPs have open access to transmission system, enabling them to supply to any distribution company in the network. All the generators compete to supply power. A power pool exchange is established to match the demand and supply. There is competition in generation, and distribution becomes transparent.

(iv) Retail Competition: This is close to the full competition as all customers also have choice of supplier, in addition to the conditions that exist in wholesale competition. Distribution is further split to retail level and retail industry is competitive.

6.2.2 Learning from IPP Experience in Developing Countries

A variety of IPP models have been used world over, including in developing countries. A 10 country study indicates the outcomes (see Figure 54) for IPPs as well as for governments for a variety of IPP policies followed by them. Learning from experience in IPP investments and PPA negotiations internationally and in Africa, there is a need to create policy, regulatory, institutional and financial frameworks that can attract IPP investments and can secure sustainable PPAs.

The study (Woodhouse, 2005) suggests the following actions for creating and managing an IPP program:

Insist on competitive and transparent bidding in allocating projects: Projects whose costs are out of line with other new power sources are particularly vulnerable to claims of corruption and improper awards. A well-designed, transparent bidding process helps to allay those concerns and also yields projects that are indeed highly competitive.

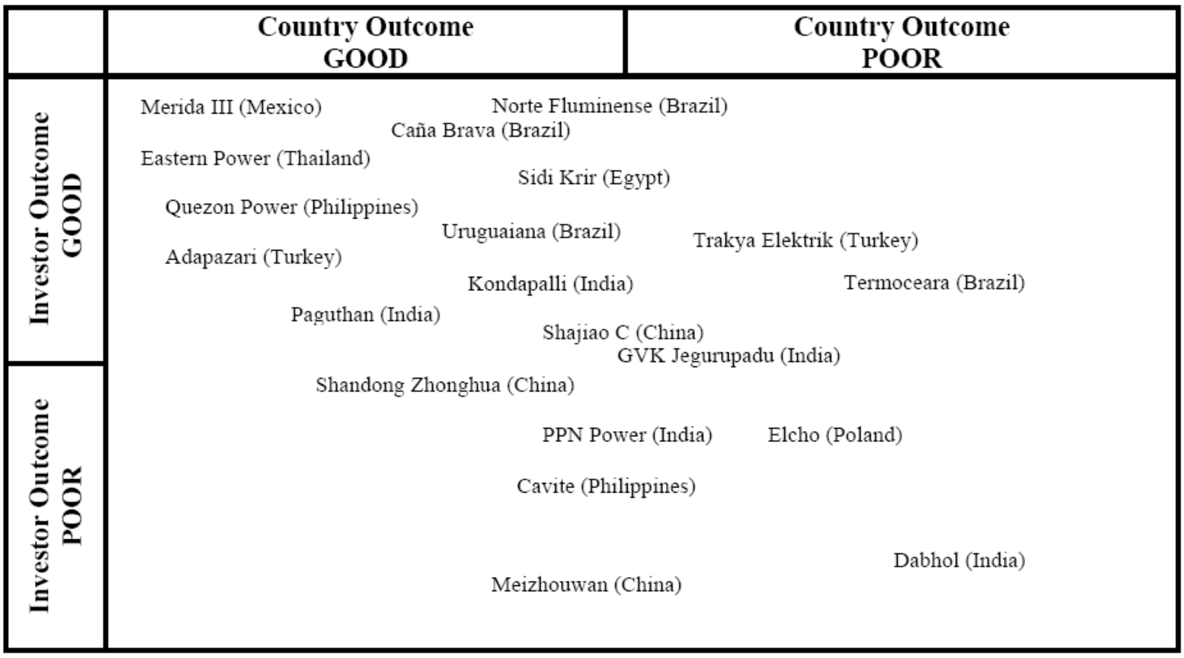

Figure 54: The Two-Dimensions of Project Outcomes for a Selection of Projects. (Source: Erik J. Woodhouse, 2005. A Political Economy of International Infrastructure Contracting: Lessons from the IPP Experience. Working Paper #52, Stanford University.)

Anticipate the need to manage stress in the private power sector: This comprises both financial stress, such as that resulting from macroeconomic shock or sudden demand fluctuations, and political stress, such as opposition from civil society or entrenched interests.

Be careful of tension between short- and long-term goals: In nearly all the IPP programs the logic for private participation included, in part, the need for long-term investment. The goals of limiting risk assumption by government in the long term and of securing high-quality investment in the near term often cut in different directions.

Be careful of the tension between power sector reform and attracting IPPs: In the 1990s, textbook reform aimed unambiguously at fully private, competitive electricity markets governed by an independent regulatory authority. Analysts imagined that these reforms would occur at the same time that private investors flooded in. Instead, reforms have yielded only a hybrid market rather than the textbook, and in some countries (e.g., Argentina and Brazil) there is movement back to a greater role for state control. In practice, the single-buyer system has allowed countries to maximize returns from IPPs, but only with extensive risk assumption by the host government or consumers that would not be sustainable if replicated on a large scale. Thus, despite appropriate caution in embracing such a model, countries can structure IPP contracts in a way that does not unduly prejudice further reforms in the distribution sector, while reaping the coordination advantages that accrue to a single buyer system.

Look beyond contracts and prices for risk management: For large scale infrastructure projects in uncertain markets, contracts and the other elements of “risk engineering” are necessary but not sufficient instruments for managing risk.

Get good contracts in form, but be flexible in reality: Contracts are important for a range of reasons, including the fact that project finance is impossible without them. Yet, arranging appropriate and clear contractual rights is one thing—enforcing them

rigidly is another. Every class of actor in the IPP casino has found it necessary or efficient to stretch beyond previously accepted boundaries. Governments have paid enormous sums for contracts that in hindsight were poorly structured.

Focus on fuel risk: The remarkable regularity with which fuel supply contributed to project outcomes across the country sample should be an enduring lesson from the first round of IPP investment.

6.3 Proposed approach to the power purchase agreement (PPA) and tariff setting

Considering the size of the Mozambique electricity market (small), single buyer model chosen by Mozambique government is suitable at this stage, as there is no room for many players. The three functions of the EDM, viz., generation, transmission, and distribution however need to be transparent through division in three different business units.

A PPA needs to be transparent, should encourage efficiency, and at the same time provide enough incentive to investors to invest. From society's point of view, a PPA should be sufficiently attractive to the IPP-investor so that he actually chooses to invest (He gets more profit from investing than not investing). On the other hand, if the PPA is too profitable there is danger of cross subsidization from the electricity sector to the potential investor.

The purpose of PPAs is to make sure that efficient investments are made in the electricity sector, that the IPPs are dispatched according to the least cost principle and that commercial actors can make a "reasonable" profit. An approach for PPAs in Mozambique is to design them as two part contracts with a fixed element and one or more variable elements. The fixed element is linked to the capital costs and the capacity of the plant. This element substantially mitigates the risk of the investor and also guarantees the buyer that a certain amount of capacity is available at specified circumstances.

The variable elements of the agreement should be linked to the actual electricity production and this part serves as an incentive to produce electricity when it is most valuable to the buyer according to the Least Cost Dispatch principle. Electricity is most valuable at day when consumption is high and the IPP replace more expensive units, based on diesel or gas. The variable elements could be formed as time-of-day payments in line with time-of-day tariffs on the consumer side. In addition to this there should also be an element describing payments when the IPP delivers other kinds of technical services to the grid (voltage control, regulation etc). This principle can however not be followed in case of wind IPPs, since they have no control over the resource (wind). In case of wind, electricity produced needs to be absorbed by the system, as and when available.

Following requirements also need to be met for efficient functioning of an IPPs based electricity system.

- There needs to be a regulator
- The distribution utility (EDM in this case) should have possibility to cover costs with tariffs. In case issue of affordability arises, subsidy should be provided by the government directly, and not through deteriorating finances of the utility, which creates opaqueness and inefficiency in the system

- Hence, tariff needs to be structured in a way to; a) recover all costs, and b) be based on the principle of marginal system costs.
- Specific support schemes for renewables such as wind will be required. Therefore, if renewable such as wind electricity is planned to be introduced, feed in tariffs may need to be planned
- IPPs must have non-distorted access to Transmission and Distribution systems.

The economic and financial evaluation was done based on a tariff of 9 US cents / kWh, which is close to current average retail selling price of the EDM. Normally, renewable energy such as wind requires incentives and feed-in-prices (which are higher than the avoided cost of the utility buying the power). The justification for higher prices is for reasons such as environmentally friendly energy source and hence external costs (to society) are less, energy security, to compensate for subsidies to conventional energy etc. EDM "operating costs" per kWh were 2.4 MT (US cents 10/kWh) in 2005 EDM Annual report, 2005), whereas the average selling price was US cents 8.50/kWh. EDM sources a major part of its energy from HCB at a very favourable rate; was 0.77 US cents/kWh in 2006. Therefore, scope for a feed-in-price for wind energy beyond 9 US cents/ kWh seems difficult. Unlike ENMO, who operates an isolated grid (and hence could sell power at US cents 14.50 /kWh), wind power has to be fed to the EDM grid and distributed by the EDM. Therefore, a price of 9 cents/kWh, with an escalation of 3% per year has been considered. A tariff, that would make wind power viable (without any other support – through grant, CDM etc.- will be very high; 16 cents /kWh.

6.4 Environmental Impact (EIA) assessment

In this section, an approach to EIA considering the special characteristics of the wind project has been discussed. First we list relevant acts and notifications of the Government of Mozambique on the EIA, and thereafter, special considerations for EIA in case of wind projects.

6.4.1 Framework for EIA in Mozambique

The following environmental policies, laws and regulations, other important legal instruments have been issued in Mozambique for environmental management, which have to be considered for the EIA also;

- National Environmental Management Programme (MICOA 1996): Contained an 'Environmental Policy', a proposal for the 'Framework Environmental Act' (subsequently passed in 1997) and an 'Environmental Strategy'. The environmental laws aim to ensure that environmental aspects are considered in any project design while using the natural resources sustainable.
- Framework Environmental Act (No. 20 of 1997): This provides a legal framework for the use and correct management of the environment with a view to promote sustainable development in Mozambique.
- EIA Regulations (Decree No. 76 of 1998), and EIA guidelines: The activities that can cause significant environmental impacts require license, which in turn requires preparation of an appropriate EIA and its approval by MICOA. EIA guidelines are applicable to a variety of development projects. There are sector specific guidelines also for EIA, for example for construction of new roads as well as road

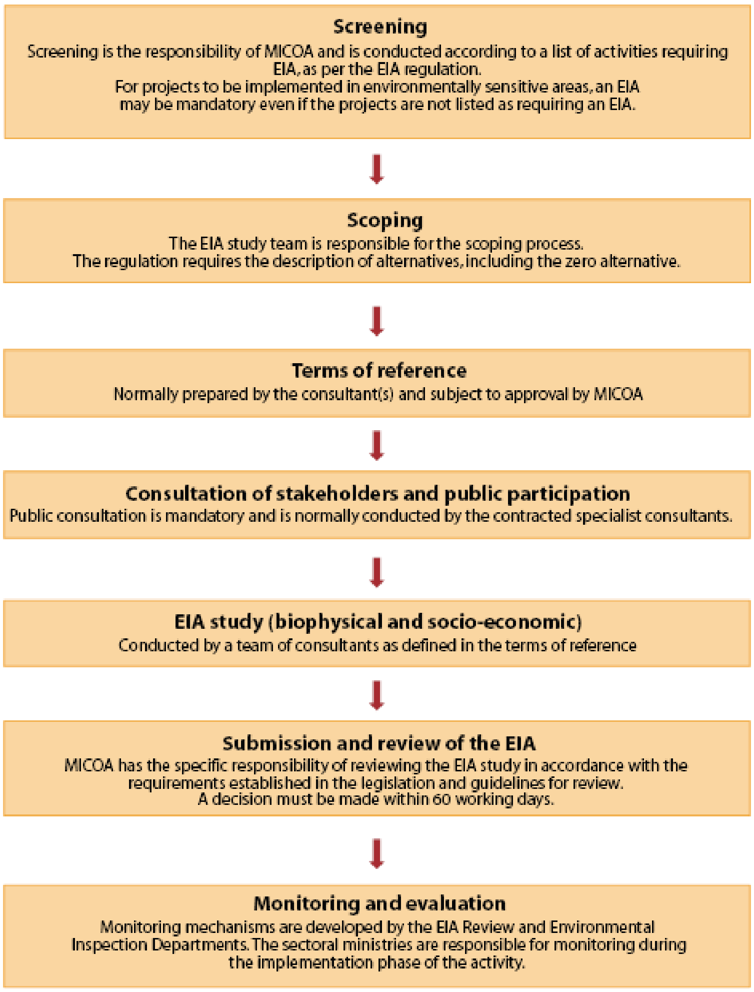

Figure 55: A snapshot of EIA in Mozambique. (Source: John Hatton, Steven Telford & Hartmut Krugmann. Mozambique, Country Report. http://www.saiea.com/saiea-book/Mozam1.pdf)

rehabilitation and maintenance. A snapshot of the EIA in Mozambique is reproduced below from Hatton John et.al. (Figure 55).

General EIA guidelines are available in several publications in public domain. For example, European Communities publication (2001); Guidance on EIA- EIS Review, prepared by , Environmental Resources Management[8].

6.4.2 EIA for Wind Energy Projects

First of all, it needs to be decided as to when an EIA is needed for a wind project. In Denmark for example, an EIA is needed for projects with wind turbines above 80 m total height, or with projects with more than 3 wind turbines. For all other projects a "screening" will be made by the regional planning authority considering the size of the project, vulnerability of the environment, and the degree and duration of impact.

If it is decided that an EIA is needed, the special features of wind energy projects, that need to be considered in an EIA are as follows:

[8] http://ec.europa.eu/environment/archives/eia/eia-guidelines/g-review-full-text.pdf.

Neighbourhood: There needs to be a minimum distance between a wind turbine and the houses in the nearest neighbourhood. In Denmark, it is needed to be no less than four times the full height of the wind turbine. Full height is considered from the ground to the tip of a blade when in the vertical position.

There may be other issues that relate to the protection of citizens, the open land, nature, landscape, agricultural interests and cultural items of historic value. People who live in the vicinity may be bothered by noise, vibrations, shadow flicker or light reflections from the blades rotating in sunny weather. This requires considering all the neighbours, distance between neighbouring houses and the proposed site. The shadow from a wind turbine moves rapidly when the blades rotate, and this can be annoying compared to a stationary shape. The report should describe how far the shadows reach at all times of year, based on the probability of sunny and windy conditions occurring simultaneously, and the layout of the wind turbines in relation to other prominent features of the landscape. Shadow flickering may need to be evaluated, for example with software tools such as WindPro. The surrounding landscape may contain protected species of flora or fauna which may need special consideration.

Noise: Mechanical noise is insignificant from the modern wind turbines. Noise originates mainly from aerodynamics, which is in form of the hissing sound from the rotating blades. At a distance of 300 metres from a 1 MW wind turbine, the expected sound level would be 45 decibels (dBA), which can be considered very low. The noise should be within the noise limits required as per the law of the land.

Visual Impact: This depends on aesthetic judgment on beauty and diversity by the community, a subjective issue. A high value may be placed on landscape amenity by some communities. There may be areas with protected designations in some countries. While specific may be earmarked for potential wind farm development in others.

Impact on Birds: Deterioration or fragmentation of habitat or disturbance to birds is considered an important issue, if the region contains rare species. Similarly, collision risk is to be considered, if migrating birds pass through the region. Through proper planning practices and appropriate siting of turbines, this can be avoided.

Water: During the construction phase there may be a risk of diesel or hydraulic oil spillage from lorries or cranes. Lubricants are used in the wind turbines and its impact on the ground water may need to be assessed. The gearbox typically contains between 280 and 350 litres of oil, but spillage may rarely occur. Surplus grease from bearings and hydraulic liquid is usually collected in trays placed under the mechanical parts. There are no exact rules as to how far from a well a wind turbine may be erected, but general recommendations suggest a minimum of 50 m from a private well and 300 m from a public drinking water source.

Waste: The issue of disposal of all sorts of waste occurring throughout the lifetime of the wind farm, from construction phase to demolition needs to be addressed. In Denmark, there is a very strict Requirement for the clean up process following the demolition of a wind farm; foundations should be removed to a depth of one meter, as in most cases the soil will return to agricultural use.

Air pollution and climate: Wind projects have positive impact on air quality and climate, and these also need to be covered in the report. Reduced emissions of NO_x, SO_2 and particles compared to alternate sources of electricity are positive impacts on air quality. At global level, reduction in CO_2 emissions is the environmental benefit.

Impacts due to socio-economic effects: There may be environmental impacts due to socio-economic changes in terms of decline or a rise in visitors to the area, or an effect on land prices. Socio-economic impacts are discussed in detail in the section 6.5.

Electromagnetic interference: The moving blades can affect radio waves and microwaves used for communication purposes. But this has not been an issue.

Others: May include impact on archaeological remnants or items of great architectural interest as well.

Offshore Wind Energy development may have different issues. A survey[9] found that that birds, visual effects and impacts on recreation were major concerns in Europe. This however is not discussed here since it is not relevant in the current context in Mozambique.

For health and safety related issues, International Finance Corporation's publication Environmental, Health and Safety Guidelines for Wind Energy Conversion Systems, July 1998 can be referred.

The EIA report – mitigation

Suggestion for mitigation of negative impacts is an EIA requirement. In case of wind project for example, light reflection from the blades can be reduced by coating the blades with non-reflecting paint, and in case of flickering, stopping turbine during periods with flickering could be a mitigation measure. Similarly, suitable suggestions for protection of aviation lights etc. may be needed.

6.5 Social Impact Assessment (SIA)[10]

We first discuss the process of SIA and thereafter briefly discuss the likely outcomes of SIA of the proposed wind energy project in Mozambique. Often, the assessment also includes economic impact of the project on the community, and hence termed as Socio-economic Impact Assessment (SEIA). The terms SIA and SEIA have been used interchangeably here.

The objective of a socio-economic impact assessment is to examine as to how a proposed development will change the lives of current and future residents of a community. A variety of indicators can be used to measure the potential socio-economic impacts of a project. These include:

- • Employment and income levels changes.
- • Changes in economic activities, consumption and demand for services.
- • Changes in housing market.
- • Changes in the quality of life of the community, indicated by HDI indicators.
- • Demographic changes etc.

The assessment involves quantitative measurement of these factors and the perceptions of community members about how the project will affect their lives. The community values therefore play an important part in a socio-economic impact assessment.

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9 http://www.ewea.org/
10 Based on http://www.lic.wisc.edu/shapingdane/facilitation/all_resources/impacts/analysis_socio.htm

Community members who may be affected by the project needs to be involved in the SEIA. Others stakeholders that should be involved may include community leaders and others community interest groups and organisations, local public agencies, local environmental groups etc.

SEIA should be seen as an opportunity to integrate diverse community values into the decision-making process. SEIA is crucial for the decision to go ahead with the project, abandon or look for an alternative project.

In a SEIA, it is very important to consider the potential impacts of development on vulnerable segments of the population. Sometimes, equity concerns may also require investigation. It needs to be investigated and ensured that vulnerable section of the population is not burdened with the cost of adverse social impacts as a result of the project. Remedial measures needs to be included in the project in such cases. Consequences of "no project" should also be examined to put the SEIA in proper perspective. SEIA can also help understand catalytic impact on development of a community due to the project, as well as negative side effects.

Socio-Economic Impact Assessment Process: The process includes; (i) Defining the scope of SEIA, and (ii) Identifying and evaluating the development impacts. Quantitative changes and community perceptions, both need to be considered in the evaluation of impacts.

(i) The scope of SEIA: Most important social and economic priorities of the community are normally considered to make the assessment manageable. Residents and community leaders are consulted through surveys and interviews on community concerns and needs, that project may impact. The design of the impact assessment needs to reflect the specific characteristics of the proposed project.

(ii) Identifying and evaluating project development impacts: This requires assessing impacts both in terms of quantitative and qualitative measures of community socio-economic well-being. Measuring community perceptions about development is as important as estimating the number of new jobs created by the proposed project.

Quantitative changes in the socio-economic characteristics of the community include changes in demographics, housing, public services, markets, employment and income, and aesthetic quality. Not all are significant in all projects and analysis can be restricted to the characteristics that may change as a result of project.

Demographic impacts include the number of new permanent residents or seasonal residents associated with the project, the density and distribution of people and any changes in the composition of the population in terms age, gender, income, educational level, health status etc. A variety of modelling techniques are available to assess population impacts.

A housing market analysis helps determine impact on demand for housing as a result of the project. Housing market demand changes may in turn impact employment and income. Location of housing is an important parameter to determine overall impact.

Market impacts include new commercial developments. These developments provide a community with products, services and conveniences important to the quality of life of local residents.

In most cases, project may directly influences changes in employment and income opportunities in communities. Such changes may be temporary (e.g. during

construction phase only) or permanent, depending on the type of project. Growth in employment places additional demands on community services and resources.

It may also be worthwhile to include impacts on the aesthetic quality of a community. Commercial development of the area and changes in the rural landscape for example, can be included in this. Aesthetic impacts may often be considered under environmental impacts, but may have a significant impact on the social well-being of the community and resident perceptions about the quality of life in the community. Therefore, these need to be considered in SEIA also. Techniques such as design review, geographical information technology, image processing technology, multi-media technology, and communications technology can be used to assess aesthetic impacts.

Community perceptions about social well-being: The attitudes community residents have toward the project and their perceptions of community and personal well-being are important determinants of the Information about attitudes and perceptions can be gathered from community leaders, as they tend to reflect the attitudes of the residents. Techniques such as surveys, focus groups, public hearings and meetings with community residents may be used to collect the data on perceptions.

Expected Socio-economic Impacts of a Wind Energy Project:

In an economy with shortages of power or unavailability of the grid, a wind energy project may have the positive socio-economic impact from the reliable supply of electricity to residents as well as public installations and institutions such as water supply facilities, health centres and schools. The availability of reliable electricity in area with erratic supplies, or where electricity was not available, may also generate employment and income through existing industry expansion or establishment of new industries in the area. The electricity, if available for use in agriculture may help increase food and other crop production. This in turn may increase farm employment and income of the poor farm labourers. Industry and agricultural entrepreneurs may increase their profit and business by saving on fuel, often diesel generators. Households may also benefit by access to electricity, and also save money by switching from expensive alternatives, often kerosene, batteries, diesel etc. They may also benefit by access to clean fuel, getting rid of local pollution and associated health impacts. Global environment may also benefit, as it often increases energy efficiency with which end consumers are provided the services. Depending on size of the project, other quality of life impacts may also be there. Similarly, displacement of the people and their livelihood concerns may be adverse impacts in a big project.

6.6 Outlining a policy framework for wind energy exploitation

From this preliminary feasibility study and discussions with stakeholders, following steps for wind energy development in Mozambique are suggested:

1. The technical study indicates potential for wind energy in some locations. But it recommends further data gathering on wind before a pilot project can be put-up. The data gathering therefore should be continued while making initial preparations for site identification and a pilot project.

2. It is also clear from the technical study that data on wind is insufficient. A wind atlas for Mozambique needs to be produced, after the ongoing wind measurements at some locations confirm the wind potential.

3. From the economic study, it has become clear that with the given energy and energy resources scenario in Mozambique, a wind power plant is not an economically viable option. Only with a combination of grant, concessional finance, CDM revenues, and tariff can make the project viable. And yet, there may be interest in developing wind energy on account of it environment friendliness, a feature which may also help access donor finance. It may be worthwhile to make preparation for one or two pilot projects, and scout for donor finance for the same. It has also become clear that banks in Mozambique will not lend to a wind farm. The pilot projects therefore will need to look for innovative financing opportunities, including donor and environmental (CDM) finance. A successfully operating pilot wind energy project may help banks in Mozambique develop confidence, taking them closer to consider financing wind energy. A pilot project will also help gain experience in wind energy installation, operation and maintenance, a pre-requisite for a full-fledged wind energy development programme later.

4. Private sector in Mozambique has yet to be developed to reach a stage to participate in wind energy development. The framework conditions in Mozambique need to be more conducive for private sector to take initiative in this area. Involvement of private sector in power sector requires market approach, which means regulation of the sector, instead of control. Current governmental concerns on price of electricity in a free market (based on the limited experience with ENMO) may throttle the development of a viable private sector. The twin issues of a healthy private sector development in power sector and access to electricity to the poor at affordable prices need not to be contradictory to each other. A direct support mechanism for the poor with viable tariffs for private sector need to be designed in such cases to meet both the objectives.

7 References

[1] Mozambique electricity master plan study. Draft Master Plan Report, Volume II – Power demand forecast. Norconsult, SwedPower, May 2004.

[2] Raising of full supply level of Corumana Dam. Prepared for National Directorate of Water by Lahmeyer International, 2003.

[3] Technical Assistance for Rural Electrification and Network Reinforcement, Mozambique. EdM. Carl Bro, 2004.

APPENDICES

List of activities in the Contract

Task 1	**Wind resource assessment**	
Activity 1.1	Specification of wind measurement equipment	30 m NRG complete systems were selected.
Activity 1.2	Installation of wind measurement equipment	2 masts have been installed and operated for one year.
Activity 1.3	Wind data collection	Wind data have been collected from the 2 masts in the period: March 2007 to March 2008.
Activity 1.4	Data analysis	Wind resources have been estimated along the coastline from Inhambane to South Africa.
Activity 1.5	Presentation of results	Results have been presented at a workshop in March 2008.
Task 2:	**Technical feasibility studies**	
Activity 2.1	Data collection and evaluation of conditions at the project sites	Data have been collected from potential sites.
Activity 2.2	Technical description	Three potential sites have been described and characterised – Salamanga, Jangamo and Chicumbane.
Activity 2.3	Cost estimates	Cost has been estimated for a 10 MW wind farm.
Activity 2.4	Estimate load forecast and operating capacity factor	The capacity factor for the wind farm has been estimated.
Activity 2.5	Financial and economic evaluation	Financial and economic evaluation has been made for a 10 MW wind farm project.
Activity 2.6	Project implementation plan	A project implementation plan for a pilot 10 MW wind farm project has been prepared.
Activity 2.7	Preparation of bidding documents	Framework for and input to bidding documents have been identified.
Task 3	**Institutional and economic feasibility study**	
Activity 3.1	Mapping of the present relevant institutional framework	Present relevant institutions has been identified and characterised.

Activity 3.2	Outlining a policy framework for wind energy exploitation	A policy for the introduction of wind power in Mozambique has been discussed.
Activity 3.3	Independent Power Producer (IPP) and ownership issues	The IPP option is described.
Activity 3.4	Tariff and model Power Purchase Agreement (PPA)	A PPA model has been discussed.
Activity 3.5	Capacity building and training	Knowledge has been transferred to DNER as on-the-job training.
Activity 3.6	Stakeholder workshop	Workshop was organised in March 2008.
Activity 3.7	Dissemination towards and engagement of the private sector	Representatives from the private sector was invited to the workshop.
Activity 3.8	Environmental Impact Assessment (EIA)	A framework for EIA has been presented.
Activity 3.9	Social Impact Assessment (SIA)	The SIA has been discussed and described.

Organisations and persons involved

Workshop agenda and participants

REPUBLICA DE MOÇAMBIQUE
MINISTERIO DA ENERGIA
DIRECÇÃO NACIONAL DE ENERGIAS NOVAS E RENOVÁVEIS

Agenda for the workshop on wind power in Mozambique
March 12, 2008
Hotel TIV

Time	**Activity**	**Observations**
08:30 - 08:45	Arrival of participants and registration	Secretariat
08:45 – 09:00	Welcome speech	DNER
09:00 – 10:30	**Technical issues** Technical feasibility studies – the presentation will cover this topics: • Data collection and evaluation of the conditions at the site • Technical description • Cost estimates • Estimated load forecast and operating capacity factor and • Financial and economic evaluation.	RISOE
10:30 – 11:00	Coffee break	
11:00 – 12:30	Discussions	Plenary
12:30 – 13:30	Lunch	
13:30 – 14:30	**ECONOMIC ISSUES** Institutional and Economic Feasibility study • Mapping relevant institutional framework, • Outlining a policy framework for wind energy exploitation • IPP,PPA.	RISOE
14:30 – 15:00	Discussions	Plenary
15:00 – 15:15	Coffee Break	
15:15 – 16:00	Project status and proposed next activities. • The way forward	RISOE
16:00 – 16:30	Summing up Closing	RISOE /DNER

List of participants

Ministry of Energy

- António Saide National Director
- João de Lima Head of Department
- Iasalde Jeremias
- Jaime Chambule

Energy Fund

- Ismael Chale
- Roque Mucanjo

Eduardo Mondlane University

- Boaventura Cuamba

Confederation of Economic Associations (CTA)

- Luís Lucas

National Institute of Meteorology (INAME)

- Benjamim B. Manhiça

Mozal

- Neels Cornelius

DANIDA

- Anders C. Pedersen

European Commission (EU)

- Fabrizio Moroni

MCM,lda

- Dulá Magide

RISO missions in Mozambique

Mission	Period	Riso experts	Activities
Mission 1a Inception	18/11 – 26/11 2006	Poul Hummelshoj	Visiting Lichinga. Identification of Pont de Ouro met-mast site.
Mission 1b Inception	4/12 – 8/12 2006	Per Norgaard	Project activities discussed, agreed on and further specified. Site selection in the Inhambane region. Meetings with the local authorities in Inhambane. Visit EdM in Inhambane. Visit Met Office in Inhambane. Meeting with Met Office in Maputo. Meeting with EdM, Maputo. Inspection of met-mast at Maputo Airport. Development of one-page project information sheet.
Mission 2 Installation	Mar 2007	Allan Vesth	Installation of the two met-masts, including training.
Mission 3 Data collection	15/9 – 23/9 2007	Per Nørgaard Jyoti Painuly	Data collection for technical, economic and financial feasibility studies. During the mission, the Ponta de Ouro met-mast site (100 km south of Maputo), the Salamanga power substation (50 km south of Maputo), the Corumana hydro power plant (100 km north-west of Maputo), the met-station at Maputo Airport and the Maputo Met Office were visited.
Mission 4 Workshop	9/3 – 15/3 2008	Per Nørgaard Jyoti Painuly	Workshop with stakeholders. Identification of the Chicumbana site.

Characterisation and evaluation of met-mast sites

Site	Location	Site description	Land issues	Grid connection	Date & Team
Lichiga	S13 E35 UTM Z36 N??m E??m ?? m				
Tofo	S23.8672 E35.5540 UTM Z36 N7358127m E760090m 30 m	The site is next to a memorial monument at a 45 m high slope towards E at a small point, 150 m from the sea with free wind from N over E to S. Enough space for the anchors for the guy-wires and good space for erection. The soil is pure sand. In addition, two 50 m (?) Vodacom lattice towers are present (Vodacom site #2506 and #2507).	?	A MW wind farm cannot be connected to the 33 kV line from Lindela over Inhambane to Tofo. A MW wind farm in the area must be connected to the substation at Lindela, 50 km SW of Tofo with 110 kV line to Maputo.	2006-12-5 PN LAJ JAC CL
Jangamo	S24.0676 E35.5377 UTM Z36 7336039 753327 46 m	No appropriate site for a met-mast was identified. A 50 m (?) Vodacom communication lattice tower is present close to the sea (Vodacom site #2508).			2006-12-4 PN LAJ JAC CL
Ravene	S24.2783 E35.3829 UTM Z36 N7312888m E741894m 60 m	No appropriate site for a met-mast was identified.			2006-12-4 PN LAJ JAC CL
Zavora	S24.5161 E35.2006 UTM Z36 N7286857m E722961m 5 m	No appropriate site for a met-mast was identified.			2006-12-4 PN LAJ JAC CL

Site	Location	Site description	Land issues	Grid connection	Date & Team
Ponta do Ouro 1	S26.7331 E32.8955 UTM Z36 N7043119m E489611m 30 m	The site is situated close to the border to South Africa, 500 m from the sea at a gab of a 70-100 m high dune, 100 km south of Maputo, and easy accessible, ? km from road 201. Good space to erect the mast. The soil is pure sand.	The site is far from any activity and the land can easily be acquired.	A 66 kV line from Maputo to Ponto do Ouro with a substation at Ponto do Ouro and with potential further extension to South Africa is planned / in preparation?	
Ponta do Ouro 2	S26.8102 E32.8862 UTM Z36 N7034577m E488689m 65 m	The site is situated at the top of a ?? m high dune. Otherwise as site 1.	As site 1.	As site 1.	

List of equipment supply

NRG equipment supply

Quantity	Item Number	Description
2	1987	TallTower 30m (100'), 152mm (6.0") diameter **Includes screw-in anchors.
1	2027	InstallKit for 30m/40m, 152mm TallTower
2	3147	Symphonie NRG Logger with (1) MMC and accessories
2	3159	Symphonie Shelter Box with Hose Clamps
2	3157	MultiMedia Card (MMC), 16MB
1	3279	DataKit4 for Symphonie Logger and iPacks
6	1899	NRG #40 Anemometer
4	1904	NRG #200P Wind Direction Vane, 10K
2	1906	NRG #110S Temperature Sensor with Radiation Shield
2	3153	Symphonie SCM Card for #110S
10	3390	Boom, Side, 1.53m(60.5"), Galv, with clamps
2	1932	Sensor Cable, 2C, 20Ga, 32m (105'), for 30m level
2	1931	Sensor Cable, 2C, 20Ga, 21m (70'), for 20m level
2	1930	Sensor Cable, 2C, 20Ga, 11m (36'), for 10m level
2	1937	Sensor Cable, 3C, 20Ga, 32m (105'), for 30m level
2	1936	Sensor Cable, 3C, 20Ga, 21m (70'), for 20m level
2	1995	Grounding Kit with Lightning Spike, 30m TallTower
1	2710	Freight, Handling, Insurance-International Ocean Freight Door-to-Port CIF Port of Maputo, MOZAMBIQUE, courtesy of NRG Systems

Supplementing supply (spareparts):

Description	Unit	Quantity
Symphonie NRG Logger with (1) MMC and accessories	Each	1
Symphonie Shelter Box with Hose Clamps	Each	1
MultiMedia Card (MMC), 16MB	Each	1
DataKit4 for Symphonie Logger and iPacks	Each	1
NRG #40C Anemometer, Calibrated, With Boot	Each	3
NRG #200P Wind Direction Vane, 10K, With Boot	Each	2
NRG #110S Temperature Sensor with Radiation Shield	Each	1
Symphonie SCM Card for #110S	Each	1
Boom, Side, 1.53m(60.5"), Galv, with clamps	Each	5
Sensor Cable, 2C, 20Ga, 32m (105'), for 30m level	Each	1
Sensor Cable, 2C, 20Ga, 21m (70'), for 20m level	Each	1
Sensor Cable, 2C, 20Ga, 11m (36'), for 10m level	Each	1
Sensor Cable, 3C, 20Ga, 32m (105'), for 30m level	Each	1
Sensor Cable, 3C, 20Ga, 21m (70'), for 20m level	Each	1

Additional supply

Qnt	Item
1	Garmin etrex GPS

Met-mast instrumentations

#	Sensor	Parameter		Range	Units
1	NRG #40	Wind speed @ 30 m	Average		m/s
2			Standard deviation		m/s
3			Minimum		m/s
4			Maximum		m/s
5	NRG #40	Wind speed @ 20 m	Average		m/s
6			Standard deviation		m/s
7			Minimum		m/s
8			Maximum		m/s
9	NRG #40	Wind speed @ 10 m	Average		m/s
10			Standard deviation		m/s
11			Minimum		m/s
12			Maximum		m/s
13	NRG #200P	Wind direction @ 30 m	Average		deg
14			Standard deviation		deg
15			Minimum		deg
16			Maximum		deg
17	NRG #200P	Wind direction @ 30 m	Average		deg
18			Standard deviation		deg
19			Minimum		deg
20			Maximum		deg
21	NRG #110S	Air temperature	Average		°C
22			Standard deviation		°C
23			Minimum		°C
24			Maximum		°C
25		Battery voltage	Average		Volt

Table 14: The parameters measured at the two met-stations and logged by the data logger every 10 minutes.

EdM operation areas

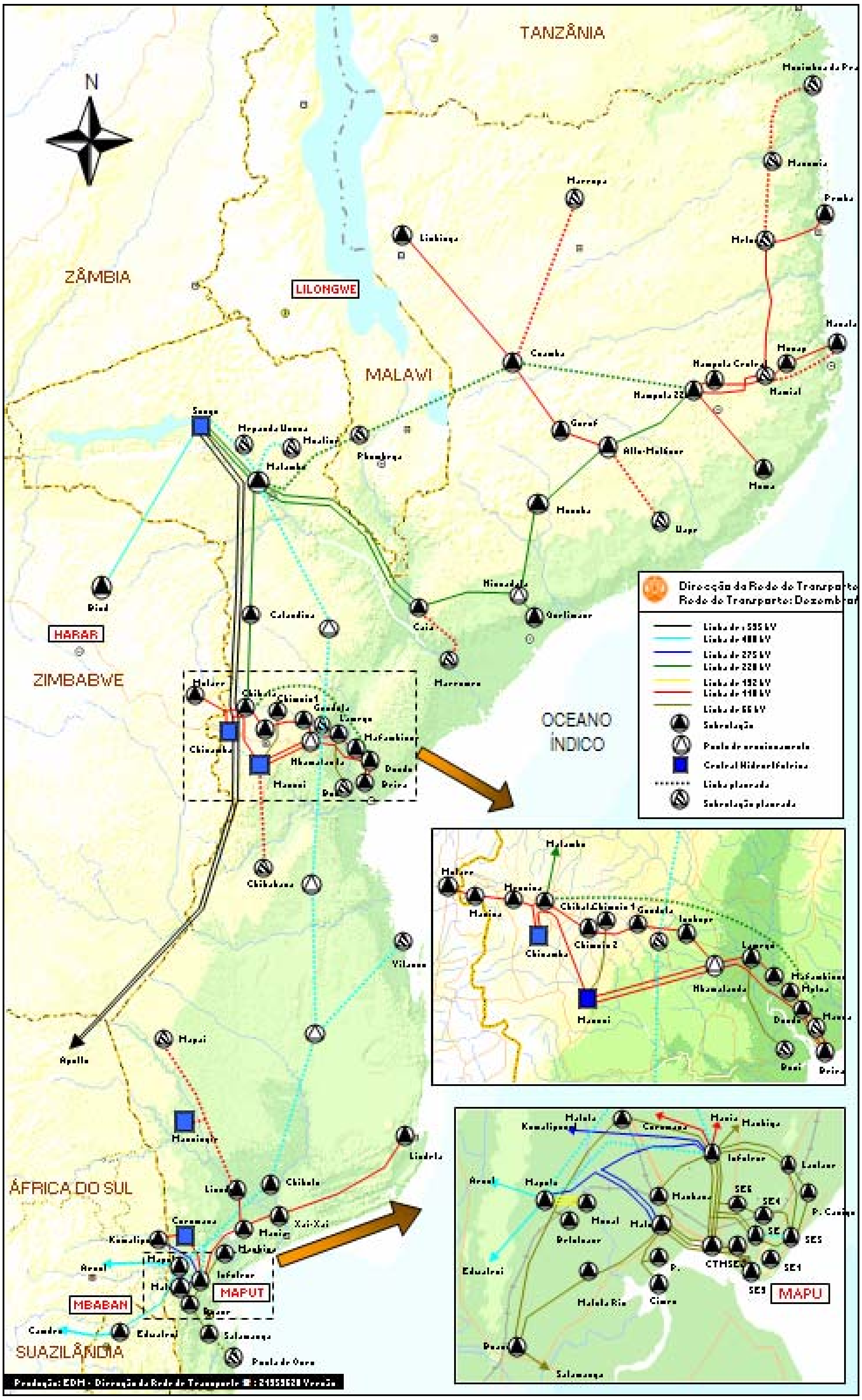
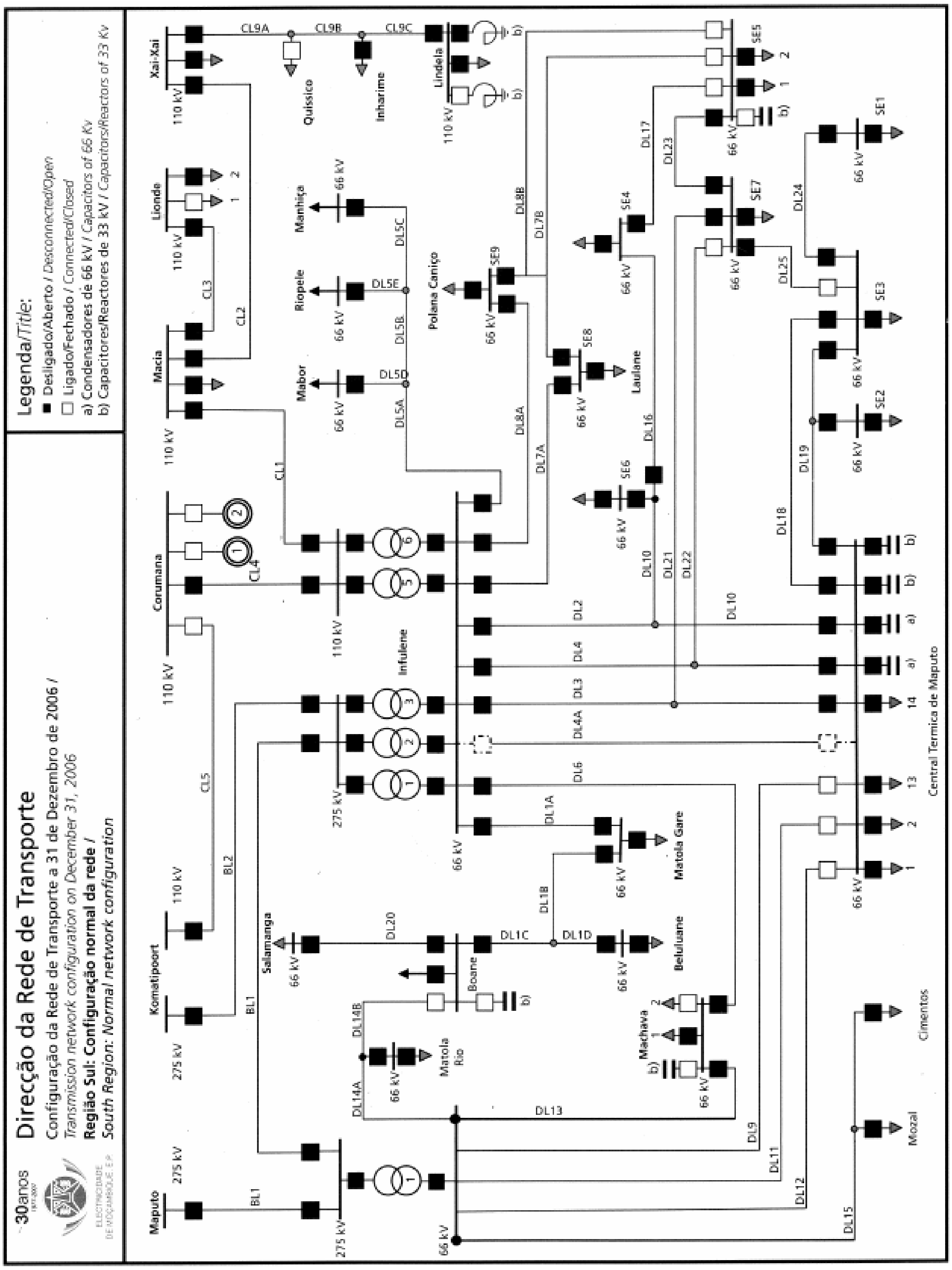


Figure 56

Region	Province	Operation area
North	Cabo Delgado	Pemba
	Niassa	Lichinga
		Cuamba
	Nampula	Nampula
		Nacala
		Angoche
Centre	Zabbézia	Gurué
		Mocuba
		Quelimane
	Tete	Tete
	Manica	Chimoio
	Sofala	Beira
South	Inhambane	Inhambane
	Gaza	Chókwè
		Xai-Xai
	Maputo	Production & transmission
		Distribution (AODM)
		Province (AOPM)


Direcção da Rede de Transporte
Configuração da Rede de Transporte a 31 de Dezembro de 2006 /
Transmission network configuration on December 31, 2006
Região Sul: Configuração normal da rede /
South Region: Normal network configuration
Legenda/Title:
Desligado/Aberto / Disconnected/Open
Ligado/Fechado / Connected/Closed
a) Condensadores de 66 kV / Capacitors of 66 Kv
b) Capacitores/Reactores de 33 kV / Capacitors/Reactors of 33 Kv
30anos
Maputo
Komatipoort
Corumana
Macia
Lionde
Xai-Xai
Quissico
Inharime
Lindela
Manhiça
Riopele
Mabor
Polana Caniço
Laulane
Infulene
Salamanga
Boane
Matola Rio
Matola Gare
Beleluane
Machava
Central Termica de Maputo
Cimentos
Mozal

Wind turbine specification

The general specifications for the Gamesa G58-850 kW wind turbine are indicated below as an illustration.

GAMESA G58-850 KW

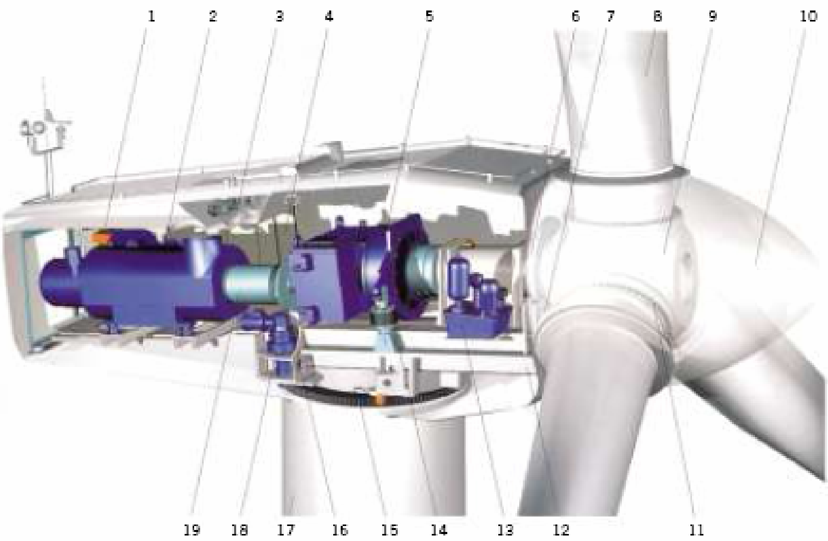
Noise control

Aerodynamic blade tip and mechanical component design minimize noise emissions. In addition, Gamesa has developed the Gamesa NRS™ noise control system, which permits programming the noise emissions according to criteria such as date, time or wind direction. This achieves the goals of local regulation compliance as well as maximum production.

Grid connection

Gamesa's doubly-fed wind turbines and Active Crowbar and over sized converter technologies ensure the compliance with the most demanding grid connection requirements.

Low voltage ride-through capability and dynamic regulation of active and reactive power.

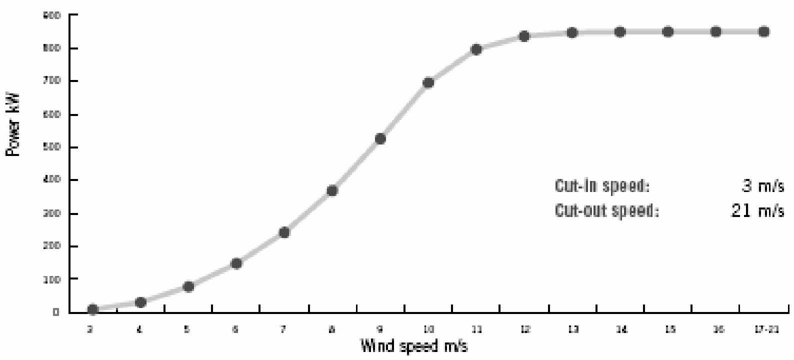


1. Service crane
2. Generator
3. Cooling system
4. Top control unit
5. Gearbox
6. Main shaft with two bearing housings
7. Rotor lock system
8. Blade
9. Blade Hub
10. Hub cover
11. Blade bearing
12. Bed frame
13. Hydraulic unit
14. Shock absorbers
15. Yaw ring
16. Brake
17. Tower
18. Yaw gears
19. Transmission. High speed shaft

Power Curve Gamesa G58-850 kW (for an air density of 1,225kg/m³)

Power curve calculation based on NACA 63.XXX and FFA-W3 airfoils.

Calculation parameters: 50 Hz grid frequency; tip angle pitch regulated, 10% turbulence intensity and a variable rotor speed ranging from 14.6 - 30.8 rpm.



Speed (m/s)	Power (kW)
3	9.7
4	31.2
5	78.4
6	148.2
7	242.7
8	368.8
9	525.3
10	695.0
11	796.6
12	835.9
13	846.8
14	849.3
15	849.9
16	850.0
17-21	850.0

Rotor

Diameter	58 m
Swept area	2,642 m²
Rotational speed	Variable 14.6 - 30.8 rpm, towers 55 and 65m Variable 16.2 - 30.8 rpm, torre 44m
Rotational direction	Clock Wise (front view)
Weight (incl. Hub)	Approx. 12 T
Top head mass	Approx. 35 T

Blades

Number of blades	3
Length	28.3 m
Airfoils	NACA 63.XXX + FFA-W3
Material	Epoxy reinforced glass fibre
Total blade weight	2,400 kg

Tubular Tower

Modular type	Height	Weight
2 sections	44 m	45 T
3 sections	55 m	62 T
3 sections	60 m	72 T
3 sections	65 m	79 T
3 sections	71 m	86 T

Gearbox

Type	1 planetary stage / 2 helical stages
Ratio	50 Hz 1:61.74
Cooling	Oil pump with oil cooler
Oil heater	1.5 kW

Generator 850 kW

Type	Doubly-fed machine
Rated power	850 kW
Voltage	690 V ac
Frequency	50 Hz
Protecction class	IP 54
Number of poles	4
Rotational speed	900:1.900 rpm (rated 1,620 rpm)
Rated Stator Current	670 A @ 690 V
Power factor (standard)	0.95 CAP - 0.95 IND at partial loads and 1 at nominal power.*
Power factor (optional)	0.95 CAP - 0.95 IND throughout the power range.*

* Power factor at generator output terminals, at low voltage side before transformer input terminals.

Mechanical design

Drive train with main shaft supported by two spherical bearings that transmit the side loads directly to the frame by means of the bearing housing. This prevents the gearbox from receiving additional loads, reducing malfunctions and facilitating its service.

Brake

Aerodynamic primary brake by means of full-feathering blades. In addition, a hydraulically-activated mechanical disc brake for emergencies is mounted on the gearbox high speed shaft.

Lightning protection

The Gamesa G58-850 kW wind turbine generator uses the "total lightning protection" system, in accordance with standard IEC 61024-1. This system conducts the lightning from both sides of the blade tip down to the root joint and from there across the nacelle and tower structure to the grounding system located in the foundations.

As a result, the blade and sensitive electrical components are protected from damage.

Control System

- The Generator is a doubly fed machine (DFM), whose speed and power is controlled through IGBT converters and PWM (Pulse Width Modulation) electronic control.
- Benefits:
  - Active and reactive power control.
  - Low harmonic content and minimal losses.
  - Increased efficiency and production.
  - Prolonged working life of the turbine.

Gamesa SGIPE

Gamesa SGIPE and its new generation Gamesa WindNet™ (wind farm control systems), developed by Gamesa, that allow realtime operation and remote control of wind turbines, meteorological mast and electrical substation via satellite-terrestrial network. Modular design with control tools for active and reactive energy, noise, shadows and wake effects. TCP/IP architecture with a Web interface.

SMP Predictive Maintenance System

Predictive Maintenance System for the early detection of potential deterioration or malfunctions in the wind turbine's main components.

- Benefits:
  - Reduction in major corrective measures.
  - Increase in the machine's availability and working life.
  - Preferential terms in negotiations with insurance companies.
  - Integration within the control system.

Crane capacity available

The following crane capacities are available in Maputo (by December 2006):

Company	Height capacity	Load capacity	Cost
Vendap	46 m	70 ton	250 USD/h + iva
Transgrua	66 m	120 ton	450 USD/h + iva

Project information sheet (English)

Wind resource assessment project in Mozambique

Short project information

Modern 1 MW wind turbine unit with 50 m hub height.

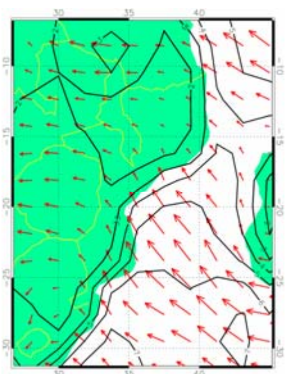
Electricity demand in Mozambique is growing rapidly, and the entire interconnected southern Africa is lacking elec-tricity. The total power generation capacity in Mozambique, mainly based on hydro power, is higher than the need, and Mozambique still has a huge unused hydro power generation potential. But wind power might be an option as well. The present project (2006 – 2008) assesses the feasi-bility of wind power as an option in Mozambique.

The project

The economic feasibility of wind power is highly dependent on the actual wind resources. According to the NCEP/NCAR global meteorological database, the best wind resources are expected in the southern part of Mozam-bique, close to the sea.

The project has collected high quality wind data during one year from two 30 m met-masts close to the sea – one at Ponta do Ouro in the south of Mozambique and one at Tofinho, east of Inhambane. The one year high quality wind data has been correlated with long term data from existing meteorological station at Maputo Airport in order to estimate the long term wind resources. The wind data collected expects to indicate the resources all along the coast from the border of South Africa to Inhambane.

Based on data collected within the project, the technical and economic feasibility has been evaluated for wind power integrated in the southern power supply system in Mozambique – the EdM Maputo Region. The Maputo power system has presently little generation capacity, is dependent on power import from South Africa, and is connected to the northern power system (with excess generation capacity) only through South Africa. The Corumana 16 MW hydro power plant is part of the Maputo system, and the Massingir 30 MW is in preparation. A direct power transmission line connecting north and south of Mozam-bique is also in preparation.



Indication of the wind speed and wind direction in Mozambique based on NCEP/NCAR reanalysis data.

Tofinho met-mast site.

The combination of hydro and wind power may be a good solution in southern Mozambique, as the seasonal variation of the wind resources seems negative correlated to the seasonal variation of the hydro power water inflow.

A proposed 10 MW wind farm located somewhere between Ponta do Ouro and Tofinho forms the basis for the study.

The Corumana hydro power plant.

The following national partners have contributed to the project:

- DNER, Ministry of Energy (project management and execution)
- INAP - National Meteorological Institute (providing long term wind data)
- EdM – Electricidade de Moçambique (evaluates the value of the wind power)

In addition, RISO National Laboratory (Denmark) acts as technical advisor for the project.

The project is supported by Danida.

Power transmission lines in the southern Mozambique.

Project information sheet (Portuguese)